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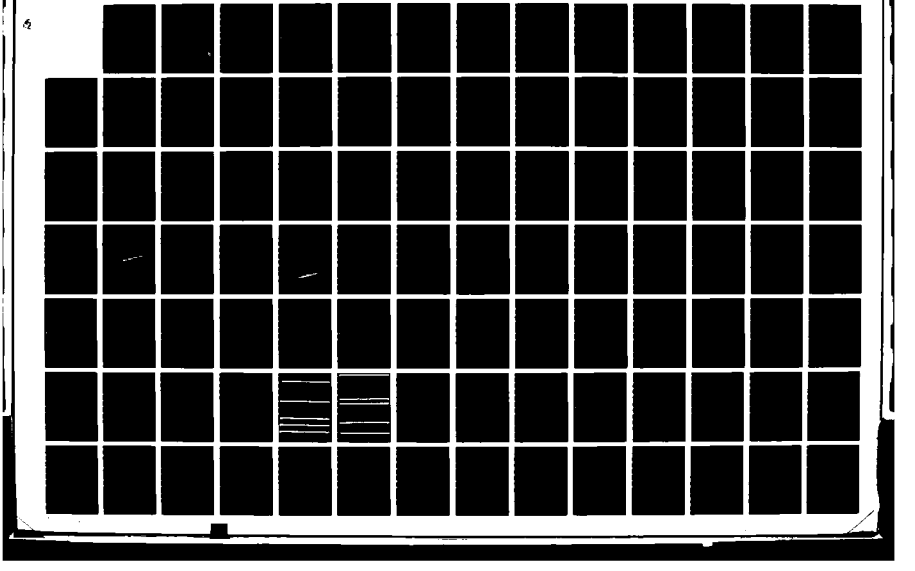

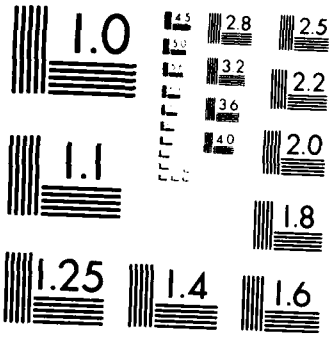

MOTION SICKNESS: A STUDY OF ITS EFFECTS ON HUMAN PHYSIOLOGY

THESIS

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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the the Degree of

Master of Science in Electrical Engineering

Pierre J. Gaudreault, B.S.

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Preface

The purpose of this thesis project was to study motion sickness by inducing it on volunteer subjects and monitoring several of their physiological parameters. Using the data obtained from the experiments, we were able to gain insight on the effects of motion sickness on humans, improve quantitative motion sickness indicators previously developed, develop a real time malaise indicator, and revise a method for determining motion sickness susceptibility.

This thesis along with theses written by Captains Michael Drylie and Edward Fix document the project. This thesis reports on findings about the effects of motion sickness on human physiology.

I wish to thank the many people who supported my efforts during this project. I thank my advisor Dr. Matthew Kabrisky for the unlimited patience and vast insight he showed to the thesis team. I thank Dr. William Czelen without whose expertise this project would not have been possible. I thank Mr. Yardich and Mr. Durham for support they provided with the motion sickness lab and equipment. I thank my thesis committee Dr. Charles Hatsell and Dr. Bruce George. And I especially thank my fellow student researchers Captains Michael Drylie and Edward Fix.

Finally, I thank my father and mother for my upbringing and their confidence in my abilities. And I thank Michele, my girlfriend, for inspiring as well as distracting me.

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Abstract

The purpose of this thesis project was to study motion sickness by inducing it on volunteer subjects and monitoring several of their physiological parameters. This was part of an ongoing project to study motion sickness at the AFIT. During this thesis period, the existing procedures and methods for collecting and analyzing data were revised, and data were collected on sixteen human subjects. Data and analysis of cardiograms, encephalograms, pneumograms, splanchnograms, and plethysmograms are presented in this thesis.

Analysis of the data revealed several findings. Heart rates increased during motion sickness for all subjects, but rates slightly decreased just prior to emesis and increased again after emesis for about half of the subjects. Some encephalograms showed high amplitude low frequency activity as in previous experiments done at AFIT, but they also showed slowed alpha activity. The pneumograms showed that intake volumes at least doubled on all subjects during motion sickness signifying the occurrence of hyperventilation. Splanchnograms showed an increase in amplitudes and frequencies of electrical activity and a decrease of mechanical activity. And plethysmograms showed blood volume in the skin decreased during motion sickness.

MOTION SICKNESS: A STUDY OF ITS EFFECTS ON HUMAN PHYSIOLOGY

I. INTRODUCTION

Motion sickness is a perplexing and expensive problem for the military services and NASA. A trained aircrew member who must be grounded for air sickness represents a substantial loss (13; 20). Both the money spent training the individual and the time spent training a replacement are lost.

It has been a problem for astronauts as well. Flight schedules are often disrupted to accommodate the problem (12). Finding the causes and a cure for motion sickness could save a great deal of money and promote smoother operations.

The disorder is characterized by a variety of symptoms; the most prevalent are nausea pallor, sweating, and vomiting. Other possible symptoms are salivation, feeling of warmth, light-headedness, depression or apathy, yawning and drowsiness, belching or flatulence, headache, tingling, and occasionally hyperventilation. They are brought on by unusual or provocative motion stimulus, either real or perceived (2:469).

The leading theory about the mechanism of motion sickness is sensory conflict theory. This theory says that when there is a conflict between different parts of the

balance system, motion sickness can result (2:474-481). The balance reflex uses sensory information derived from several different senses; primarily the vestibular, or inner ear, and the visual system. There is also input from the somatic senses (senses which report the position of body parts and pressure on various surfaces) (6:309-310, 323). If the brain perceives these various signals to be in conflict, motion sickness can result.

There have been two primary avenues of motion sickness treatment: drugs and biofeedback. Each has been somewhat successful in different circumstances.

Drug treatments are the easiest method to apply for alleviating motion sickness; however, drugs have undesirable side effects. In fact, aviators flying solo are prohibited from taking anti-motion-sickness drugs (2:491).

Bio-feedback is a promising treatment method for long term protection. The School of Aerospace Medicine (SAM) at Brooks MC has had success using skin resistance, muscle tension, and skin temperature as feedback parameters under Coriolis stress. Of the aircrew members treated this way, about 84% in one study were returned to flying status (13:119-121). A problem with biofeedback, however, is identifying physiologic parameters that are good indicators of motion sickness and amendable to voluntary control.

Ashton Graybiel and his team took a first step by developing a standard scale for measuring motion sickness discomfort (7). Others have measured skin potential and

resistance and correlated them with discomfort (10:141). This provides the basis for selecting parameters for biofeedback treatment, leading to recent Air Force Institute of Technology (AFIT) thesis efforts.

In 1983, Captains Earl and Peterson first performed AFIT motion sickness research sponsored by SAM to develop a biofeedback system. Their effort, carried on by Fitzpatrick, Rogers, and Williams in 1984 and by Jarvis and Uyeda in 1985, involved automating data collection and biofeedback parameter presentation so the work formerly performed at SAM could be performed at other bases to reduce cost (4). This effort ultimately proved unsuccessful due to problems with computer equipment. During the course of the experiments, however, the researchers learned a great deal about gathering and analyzing biophysical data and constructed several physiologic sensors to gather a wide range of data (4;11). In 1984 Fitzpatrick, Rogers, and Williams suggested building an automated motion sickness prediction model (4:6-1). This has been the thrust of more recent thesis efforts at AFIT (9;16;18).

In 1986, Hartle, McPherson, and Miller began integrating the subject's report of discomfort with the other data and correlated the reports with Graybiel's model (9:53-54; 7). Using automated statistical methods, they were able to establish positive relationships between several physiological parameters and the reported motion sickness

index (9:55). This led to development of equations relating several parameters to motion sickness (9:97; 16:59; 18:84).

Summary of Current Knowledge

Several important pathological findings also came out of the 1986 research effort in the areas of galvanic skin response, electroencephalogram, heart rate, skin pallor, respiration, and gastro-intestinal activity.

Galvanic Skin Response. Other work in the field has shown a positive relationship between nociceptive stimuli and increasing skin conductance (22:420,421). This agrees with the AFIT work (16:37).

Gastro-Intestinal Activity. The AFIT researchers found that stomach (EGG) and intestinal (ESG) signals can be separated on the basis of the nature of their frequency of electrical activity (9:108).

Electroencephalogram. One of the most exciting discoveries in 1986 was the existence of extremely high amplitude (1 - 5 millivolts), low frequency (0.1 - 0.2 Hertz) waves (1). This previously unknown phenomenon may hold a key to understanding motion sickness. According to Dr. William Czelen, EEG responses of these amplitudes but at higher frequencies have been seen during tonic-clonic seizures, hypercarbia, and asphyxia. It is possible that anticonvulsant drugs may prevent or lessen nausea. This possibility has tremendous implications for aircrew rehabilitation and space flight.

Heart Rate. Although subjects were instructed to halt the experiment just before emesis, one subject inadvertently continued through emesis. He was one of a group of subjects who demonstrated sinus arrest, i.e., the main pacemaker of the heart temporarily ceased its function and the heart rhythm converted to a junctional or ventricular one at a slower rate (35 - 40 beats per minute). When the subject vomited, his heart rate nearly tripled immediately (18:66-67), converting to a sinus tachycardia. All subjects showed increasing heart rate until reporting quite high symptom levels, and then decreasing heart rate until just before emesis. Several later subjects who volunteered to continue to emesis showed the same speedup after emesis, although the sinus arrest condition did not necessarily occur.

Skin Pallor. Jarvis and Uyeda found skin pallor patterns linked to motion sickness in 1985 (11:87-88). Hartle, McPherson, and Miller also found pallor changes in 1986, but their data seem to suggest the face flushes while the hands become more pale (16:39). This may have been due to sensor placement problems and unrelated to actual blood flow (1). The problem remained to be resolved.

Respiration. Hartle, McPherson, and Miller found that "the number of breaths increased by approximately 20 percent . . . and the respiratory contribution from the diaphragm increased by about 50 percent" (18:68-69).

Electrosplanchnogram. Hartle, McPherson, and Miller found that the electrointestinogram signal "increased by

almost 500 percent" (18:73) and that the electrogastrogram signal "frequency shifts from .12 Hz to .06 Hz" (18:77).

Problem

The purpose of this present study was to collect and analyze biophysical data relating to motion sickness, test the accuracy and improve upon motion sickness predictors developed by previous AFIT thesis teams, and develop a real-time processor to predict a subject's level of motion sickness.

Assumptions

The assumptions for this research effort are:

1. Motion sickness induced in the laboratory is the same disorder as that found in the real world.
2. The physiological readings have a definite correlation to the degree of motion sickness.
3. Biofeedback techniques developed as a result of statistical data analysis of physiological signals can be used to control or predict motion sickness.

Scope

This is a follow-on research effort to continue the study of motion sickness at AFIT by performing experiments on more subjects and improving methods of data analysis. This research team experimented with changes in the data analysis equipment. The scope of this research was limited to:

1. Collecting new motion sickness data on at least 20 volunteers.
2. Standardizing the test procedures.

3. Improving those sensors that proved unreliable in the past.

4. Testing and improving the mathematical models already developed to predict the subjective degree of motion sickness.

5. Integrating new equipment and software into the experimental procedures including:

   a. a differential stethoscope for monitoring stomach sounds;

   b. a 16-channel bank of low pass filters to reduce electrical noise;

   c. a 16-channel strip chart recorder;

   d. data acquisition and analysis software for the Zenith Z-248 computer.

Materials, Equipment, and Software

Materials. Materials include disposable electrodes, alcohol cleaning pads, Beta format video tapes, diskettes, Subject Questionnaires and Histories, and 16-channel thermal strip chart paper.

Equipment. The equipment included the following:

1. The powered rotating chair with the following physiological sensors constructed by Dr. Czelen:

   a. electrocardiograph;

   b. two thermistors to measure skin surface temperature;

   c. two electronystagmographs to measure eye movement;

   d. galvanic skin response sensor to measure skin resistivity;

   e. two photo-plethysmographs to measure pallor;

   f. two electrosplanchnographs to measure gastric and intestinal electrical skin surface potentials;

g. two pneumographs to measure respiration;

h. ballistocardiograph to measure cardiac induced thoracic oscillation;

i. three electroencephalographs to measure brain wave activity.

2. The Zenith Z-248 personnel computer with peripheral units including an 8-channel analog-to-digital converter, and wave form scroller.

3. The Marshall Electronics' Astropulse 90 sphygmomanometer.

4. The SOLTEC model 8K20 series 16-channel strip chart recorder.

5. The Kyowa Dengyo 14-channel Beta tape recorder.

6. The AMPEX FR 1300 16-track FM tape recorder.

7. The 16-channel low pass filter bank constructed by Dr. Czelen.

8. The INTECH Systems' DIF-STET differential stethoscope.

9. The Spiropet pocket Spirometer.

10. The Cyborg Thermal P642 digital thermometer.

Many of the measurements that were made were only possible because of the equipment Dr. Czelen designed and built.

Software. The software included packages for both data analysis and acquisition. Commercial software packages included DATAQ Instruments' Codas for digitizing and displaying wave forms, MacMillan Software's Asystant for numerical and statistical analysis, and Metrabyte's C Tool for driving an analog-to-digital converter. The researchers developed software to calculate and report the subject's degree of motion sickness in real time.

Other Support

Dr. William Czelen (M.D., B.S.E.E.) provided necessary medical expertise for screening volunteers. In addition, he observed all experiments to ensure the physical well-being of all subjects. Finally, he provided technical support through circuit design.

II. Experimental Changes from the Previous Year

This experiment was a continuation of work performed in previous years by Hartle, McPherson, and Miller, by Jarvis and Uyeda, and others (4; 9; 11; 16; 17). The experimental procedure consisted of spinning a volunteer subject about the z-axis in a powered rotating chair at a constant, controlled speed, and gathering up to 21 channels of physiological data as the subject tilted his head out of the plane of rotation to elicit a motion sickness response. The subject reported his discomfort by a numerical score from 1 to 10, where 1 meant the subject was asymptomatic and 10 meant emesis was imminent. The data were then analyzed by appropriate statistical techniques to determine relationships between the parameters and a computer model was developed to compute in real time a prediction for the subject's reported numerical score. More detailed descriptions are available in the previous theses and in the research protocol in appendix A of this thesis. Following are the major changes from the previous experiments.

Environment

The motion chair is presently installed in a unair conditioned environment, it was necessary to take advantage of the cooler morning hours for experiments. When experiments were conducted during high ambient temperature, thermal sweating regularly caused electrodes and sensors to

come loose from the subject's skin. Partitions were set up surrounding the motion chair and a parachute was suspended above it to enclose the area. A room air conditioner was installed to help control the environment immediately around the chair. In this way, it was sometimes possible to maintain the temperature in the ideal 22 to 24° C (71 to 75° F) range (26:418) when ambient air temperature would otherwise have prevented experimental runs.

Procedures

The order of preparation of the subject was changed to minimize the amount of time the electrodes were attached. The physical exam was done first, then the plethysmographs were calibrated. The body electrodes and sensors were attached before the subject mounted the chair, and the leads were connected afterwards. The pneumographs were then calibrated, and the facial electrodes and sensors were attached. Finally, the eyes were taped and the subdermal electrodes were inserted. This method minimized sensor losses due to loosening of the adhesive by perspiration.

Sensors

Electroencephalogram. The previous thesis team discovered extremely low frequency, high amplitude electroencephalogram signals associated with motion sickness. To eliminate the possibility that these signals were a sweat induced artifact, subdermal electrodes are now used.

Skin Pallor. The plethysmographs used before had a red LED and a photo transistor to measure the change in skin reflectivity due to flushing. However, flushed skin looks darker because the hemoglobin absorbs shorter wavelengths of light and reflects only red. Thus, the reflectivity of skin in red light changes very little, but the reflectivity in other colors (like green) changes dramatically. The LEDs have therefore been changed to green to take advantage of this effect. Also a second, phototransistor, covered by opaque paint, has been added to each sensor for temperature compensation. Finally, the adhesive used to hold the sensors in place irritated the skin of many subjects, masking any skin color change due to blood flow change. The plethysmographs are now held in place by taping over the top of the sensor. These changes greatly improved the sensitivy; therefore, coverings for shading against external light are no longer used. Because of these changes, the skin pallor data gathered before these changes has not been used in this study.

Gastro-Intestinal Measurements. A phonosplanchnogram has been added to the data collected. The sensor is a battery powered, self contained stethoscope with differential inputs. It is attached to the central abdominal region and records bowel sound activity. The output is recorded with tne FM data recorder.

Recording and Processing Equipment

The previously used Bushmark strip chart recorders have been replaced by a Soltec model 8k26 16-channel chart recorder. It uses heat sensitive paper rather than ink, and is much easier to operate than the old recorders.

A Zenith 248 computer with an 8-channel analog-to-digital converter board was used to digitize data and analyze it. The computer was also used to analyze the data in real time and could be used to provide biofeedback information.

The previous researchers had problems with 60 Hz hum in their data. To solve the problem, a 16-channel active filter bank has been added to the data circuit. It uses active two pole low pass filters with 6 dB points set at 30 Hz. These filters eliminated the 60 Hz noise from the recorded data.

III. Experimental Procedure and Sensors

This chapter describes the procedure and sensors presently used for AFIT motion sickness experiments.

Procedure

The following is a complete outline of an AFIT motion sickness experiment. It is presented to give an understanding of the steps involved in an experiment and demonstrate the sensor placements. Most steps contain a single sentence to make them easy to follow and to give researchers a check list. Calibrations done during the experiments can be found in appendix C, and the procedure for a susceptibility test is in appendix B. Novice researchers should read and understand the procedures and practice calibrations prior to an experiment.

Before Experiment (several days prior).

1. Screen the subject.
    A. Discuss subject's experience with motion sickness.
    B. Explain the experimental procedure.
2. Perform a susceptibility test (see appendix B).
3. Give the subject the appropriate forms and questionnaires (see appendix A).
    A. Physiologic Characterization of Motion Sickness Subject Consent Form.
    B. Addendum to the Consent Form.
    C. Patient Questionnaire (Form No. 405) Medical History.

D. AFIT Motion Sickness Laboratory Motion Sickness Questionnaire.

Pre-experiment (1 hour prior).

1. Test battery powered equipment.

   A. Circuit card rack.

   B. Low pass filter box.

   C. Differential stethoscope.

   D. Microphone.

   E. Cassette player (if in use).

2. Prepare recording equipment.

   A. Magnetic tape recorders.

   B. Strip chart recorder.

3. Prepare supplies.

   A. Electrodes.

   B. Alcohol pads.

   C. Adhesives.

Prepare Subject and Equipment.

1. Perform physical exam (see appendix D).

* * * NOTE * * *

Sensor types, placement, and locations can be varied. This procedure contains standard placements during this thesis period.

2. Calibrate photo-plethysmographs (see appendix C).

3. Calibrate galvanic skin response sensor (see appendix C).

4. Clean body surfaces with alcohol pads where electrodes will be applied (see Fig. 1 and table 1) and allow to dry.

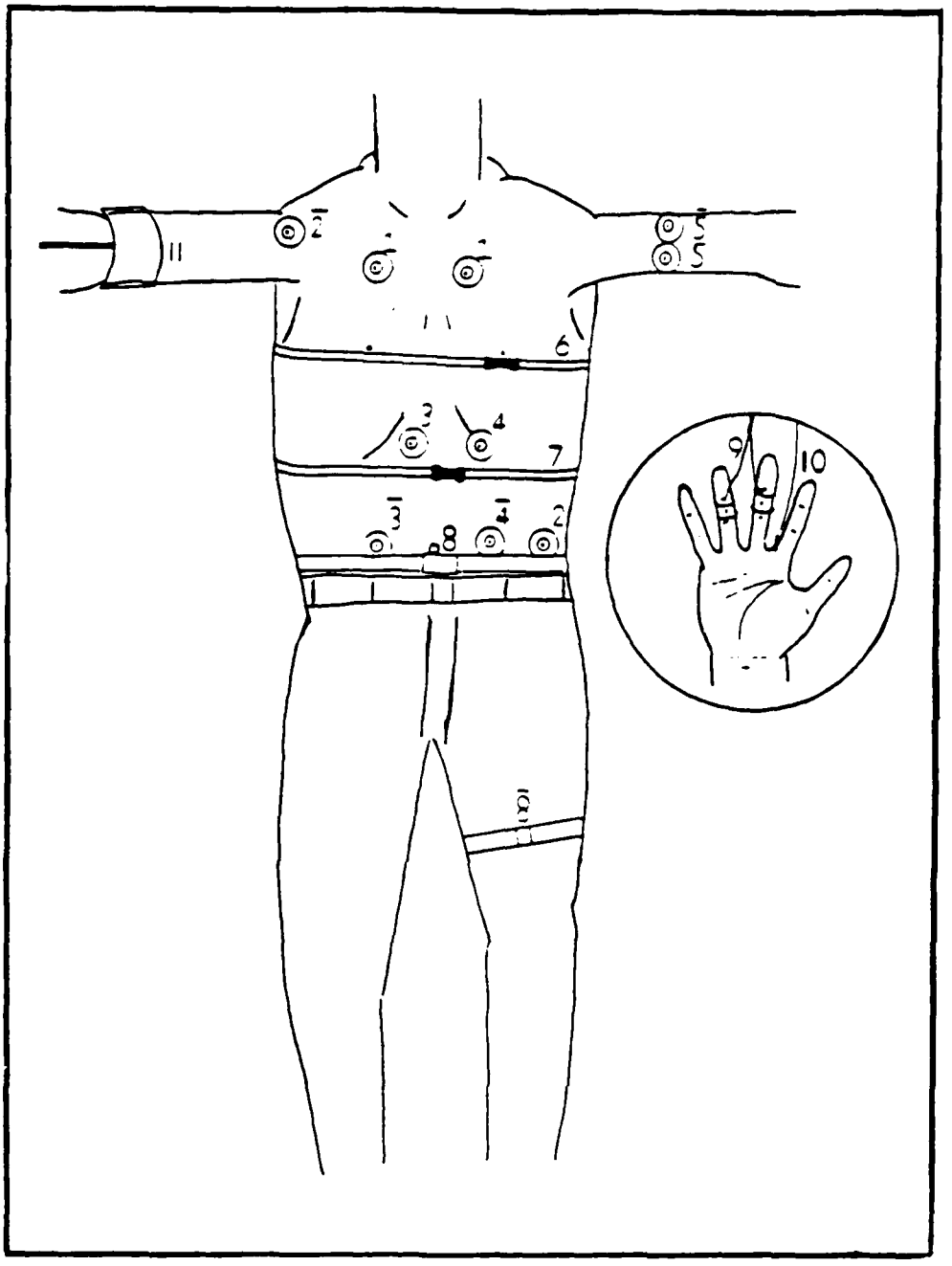


Fig. 1 Body Sensor Placements. Differential inputs for each amplifier are represented with the same number. Numbers representing inverting inputs are capped with a bar.

Table 1.

Sensor Placements from Figs. 1 and 2

Number	Name	Comments
1	Ground	NDM electrodes
2	Electrocardiograph	" "
3	Electrosplanchnograph 1	" "
4	Electrosplanchnograph 2	" "
5	Electrosplanchnograph 3	used to detect artifacts
6	Pneumograph 1	thoracic respiration
7	Pneumograph 2	abdominal respiration
8	Phonosplanchnograph	
9	Galvanic Skin Response sensor	
10	Peripheral Temperature sensor	tape over sensor
11	Blood Pressure sensor	
12	Horizontal Electronystagmograph	Huggable electrodes
13	Vertical Electronystagmograph	" "
14	Facial Temperature sensor	tape over sensor
15	Photoplethysmograph 1	" "
16	Photoplethysmograph 2	" "
17	Electroencephalograph A	subdermal electrodes
18	Electroencephalograph B	" "
19	Electroencephalograph C	" "

5. Attach body electrodes.

   A. Electrocardiograph.

   B. Electrosplanchnographs.

   C. Grounds.

6. Put on strapped equipment.

   A. Chest pneumograph.

   B. Stomach pneumograph.

   C. Phonosplanchnograph.

7. Help subject mount chair.

8. Connect body leads and sensors.

9. Put on right arm sensors.

   A. Peripheral Temperature sensor.

B. Galvanic Skin Response sensor.

C. Blood Pressure sensor.

10. Calibrate pneumographs (see appendix C).

11. Clean surfaces of the face with alcohol pads where electrodes will be applied (see Fig. 2 and table 1).

12. Attach facial electrodes.

13. Attach facial leads and sensors.

A. Vertical electronystagmograph.

B. Horizontal electronystagmograph.

C. Facial Temperature sensor.

D. Photo-plethysmographs.

14. Tape air sickness bag to the subject's left hand.

15. Tape eyes shut.

16. Insert subdermal electrodes (entire procedure, including sterilization, is performed by a physician).

17. Ask the subject to move eyes up, down, left, and right and label the movements on the strip chart recorder.

18. Ensure signal fidelity on recording equipment.

19. Clear area around chair.

Begin Experiment.

1. Turn on the chair power by pushing up the AC power control breaker and press the reset button on the right console (if the program control start/stop button is not lit, press it also).

2. Record 1 minute of baseline data.

3. Slowly rotate the chair right, using the control knob for left and right motion and the angular velocity gauge on the middle console, to the predetermined speed.

4. Wait one minute (for the subject to stabilize).

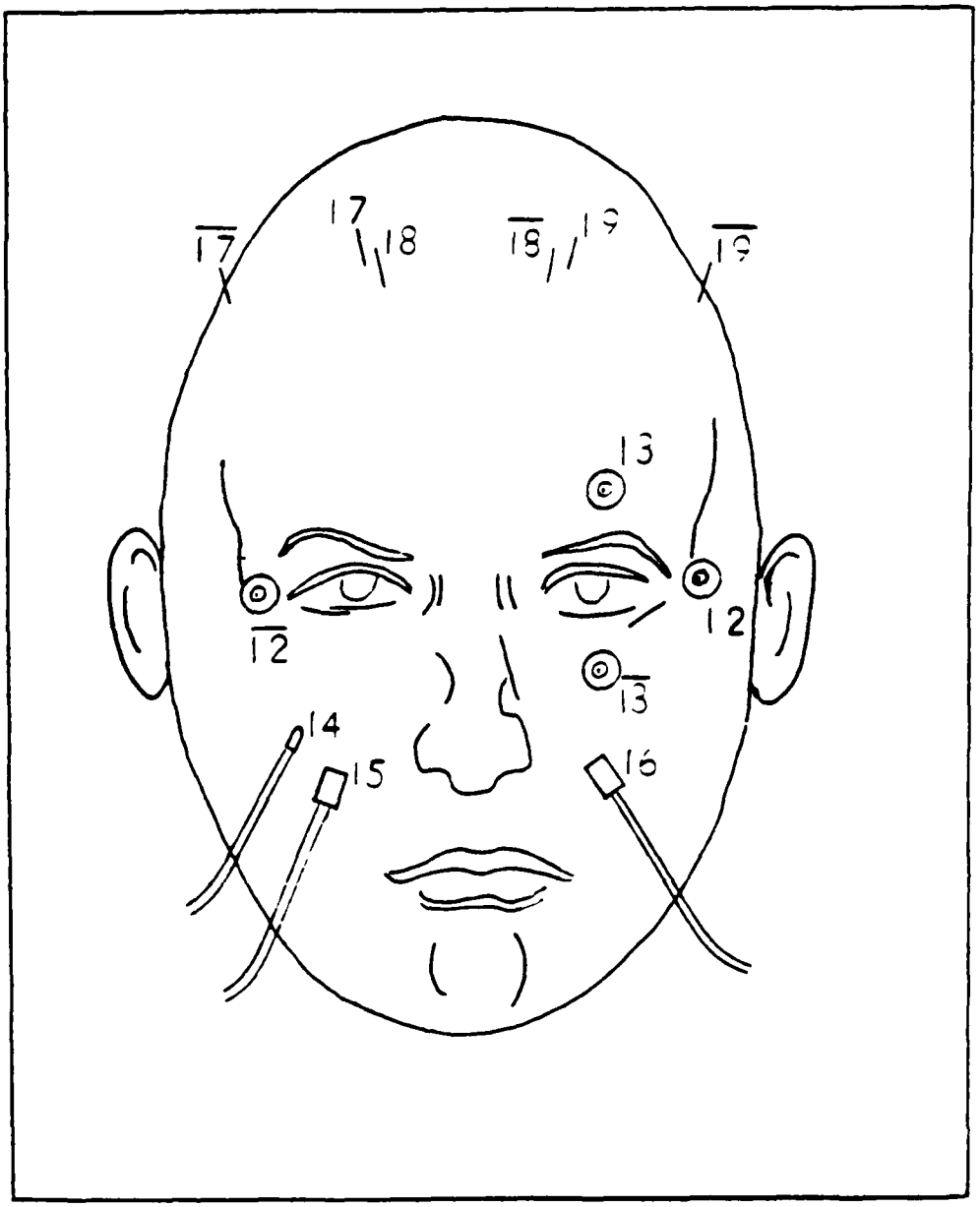


Fig. 2 Facial Sensor Placements. Differential inputs for each amplifier are represented with the same number. Numbers representing inverting inputs are capped with a bar.

* * * Note * * *

Perform steps 5, 6, and 7 simultaneously.

5. Order head movements (9:152).
6. Query subject about symptoms.
7. Record events on strip chart.
   A. Beta and Ampex counters.
   B. Head movements.
   C. Symptoms.
   D. Unusual events.
8. Stop head movements when one of the following apply.
   A. When subject requests to end the experiment.
   B. After emesis.
   C. At the physicians discretion.

End Experiment.

1. Instruct subject not to move head.
2. Allow subject's symptoms to begin decreasing.
3. Slow chair.
   A. Slow at approximately 5 RPM per minute.
   B. Query subject about symptoms.

* * * * * * * * * * * * * WARNING * * * * * * * * * * * * *
*
* CEASE DECELERATION IF THE SUBJECTS SYMPTOMS WORSEN *
* AND DECELERATE SLOWER AFTER THEY STABILIZE *
*
* *

   C. Turn off the chair power after it stops rotating.

4. Allow subject's physiological signals to return to normal.

5. Stop recordings at physician's discretion.

   A. Turn off equipment.

   B. Disconnect all sensors.

   C. Help subject dismount.

6. Name and date all recordings.

7. Debrief subject (if requested).

8. Release subject at physician's discretion.

9. Clean-up area.

10. Check battery powered equipment (replace or charge batteries if necessary.

11. Check supplies.

   A. Electrodes.

   B. Alcohol pads.

   C. Adhesives.

Sensors

Because of the continuing research, sensor circuits are constantly being revised by Dr. Czelen. A system description of the AFIT Motion Sickness Lab equipment was given by Hartle (9:32-52). Major equipment changes from the previous year were discussed in chapter 2 of this thesis. Current sensor circuit descriptions and specifications from Dr. Czelen's notes follow, and the latest schematic diagrams are are shown in appendix E.

General Considerations. Amplifiers used as bioelectric potential sensors must incorporate several considerations in their design. All amplifiers had high impedance to prevent application of current of more than several microamperes to

the subject. The amplifiers were also battery powered as an additional safeguard. The high gain alternating current (AC) amplifier designs included 0.005 Hz cutoff provided to block any direct current (DC) offsets generated by the electrolyte in the electrodes. Most designs used differential input instrumentation field effect transistor (FET) operational amplifiers to provide high impedance and very low drift.

Electrocardiograph. The electrocardiograph used silver/silver chloride electrodes and an amplifier with a frequency range of 0.05 to 20 Hz and a voltage gain of 55 to 65 decibels (dB).

Photo-plethysmograph. Two photo-plethysmographs using one circuit card employed green light emitting diodes and a Darlington photo transistor to detect changes in surface reflection. A DC amplifier with a 5 Hz high frequency cutoff amplified the output of the photo transistor. A matched photo transistor, covered with opaque paint, in a balanced inverting circuit compensated for temperature induced drift.

Pneumographs. Two pneumographs using one circuit card employed dual strain gauges each mounted in circumferential straps. Each strain gauge pair was assembled into a Wheatstone bridge network and provide a variable voltage as a function of body wall expansion and contraction. The outputs of the sensors were amplified by an AC amplifier with a response of from 0.005 to 5 Hz. The output of the circuit used for thoracic respiration was also the input of the ballistocardiograph circuit located on the same circuit

card. The ballistocardiograph circuit was a high pass filter with a 1 Hz low frequency cutoff.

Galvanic Skin Response. The galvanic skin response sensor shared a circuit card with the temperature sensors. It employed gold plated electrodes directly applied to the volar (palm side) surfaces of the fingers. A pulsating AC constant current source was used to apply a potential across the electrodes. Changing skin resistance caused voltage across the electrodes to change. The variable voltage drop was applied to a DC amplifier with a 5 Hz upper cutoff frequency.

Electrosplanchnographs. Three electrosplanchnographs, each on an individual circuit card, employed silver/silver chloride electrodes and BI-FET^{TM} (14) differential amplifiers. The circuits had frequency ranges from 0.025 to 0.3 Hz and 55 to 60 dB voltage gains.

Electronystagmographs. Two electronystagmographs, each on an individual circuit card, used miniature silver/silver chloride electrodes and BI-FET^{TM} differential amplifiers. The circuits had frequency ranges from 0.1 to 15 Hz and voltage gains of 60 dB.

Temperature. Two temperature sensors were used, both employing miniature thermistors. One sensor's thermistor was part of a Cyborg Thermal P642 digital thermometer. The other sensor's thermistor was connected to a balanced bridge network which is applied to a differential DC amplifier. The amplifier had a high frequency response of 2.5 Hz; a 1 degree

Fahrenheit temperature change corresponds to a 0.5 volt change. Two identical circuits of this type (only one was used in this series of experiments) shared a circuit card with the galvanic skin response sensor.

Electroencephalographs. Three Electroencephalographs on one circuit card used platinum subdermal electrodes and high gain BI-FET^{TM} instrumentation grade differential amplifiers. The circuits had frequency ranges from 0.5 to 20 Hz. The low frequency roll off was 3 dB per octave, and voltage gain was maintained near 80 dB at midband.

Blood Pressure. Blood pressure was taken by remote control with a modified Marshall Electronics' Astropulse 90.

Phonosplanchnograph. The phonosplanchnograph was an INTECH Systems' DIF-STET differential stethoscope. This device was an electronic stethoscope with two phonosensors. The device was used to measure stomach sounds, but the second phonosensor was attached to the leg and set in a differential mode so that is could cancel ambient noise.

IV. Data Interpretation and Results

This chapter discusses the interpretation of data collected during motion sickness experiments. Data discussed are cardiograms, encephalograms, pneumograms, splanchnograms, and plethysmograms. Other parameters such as galvanic skin response, nystagmograms, and temperature are discussed by Drylie (3), and curve fitting of parameters to synthesize a motion sickness indicator equation is discussed by Fix (5).

During AFIT motion sickness experiments, subjects rated their subjective motion sickness on a scale from 1 to 10 as discussed in chapter 2 to enable the researchers to develop a mathematical model for a biofeedback system. This reporting method, although well known to experimental psychologist and well proven historically, was not convenient for data interpretation or plotting results because subjects did not always report all numbers, and they often retreated and advanced within a small numerical range. A scale with a broader resolution was needed in order to more easily demonstrate motion sickness levels in data tables and graphs. Hence, the 1 to 10 rating scale was converted to a level of severity rating scale similar to Miller and Graybiel's (17:8). The symptom levels in the 1 to 10 rating scale correspond to levels of severity as listed in table 2.

A pool of 16 usable data sets from a group of 22 subjects had been collected at the time of this analysis;

however, individual data parameters that had questionable signal fidelity were eliminated from the analysis. Some

Table 2.

Symptom Scale Conversion

1 to 10 Scale	Level of Severity Scale*
Control (prior rotation)	Control
2	M I
3 - 4	M IIB
5 - 6	M IIA
7 - 9	M III

* M followed by a Roman numeral represents the malaise severity corresponding to the scale given by Miller and Graybiel (17:8).

signal channels were corrupted or lost completely because of equipment problems such as contacts becoming loose or circuit elements degrading. In particular, only two sets of data could be collected for the plethysmographs because changes to the circuits and procedures discussed in chapter 2 were not completed until late in the experimental stages.

Data were analyzed using two methods: strip recordings were used where data could be extracted visually, such as in determining heart rates; and magnetic tape recordings were used for data requiring spectral analysis and time or frequency plots. Two software packages, CODAS and Asystant, supported the later form of analysis. Data were converted to digital format using CODAS. Data with only low frequency components such as electrosplanchnogram and respiration were converted at 5 samples per second, while data with higher frequency components such as electroencephalogram were

converted at 50 samples per second. The second software package, Asystant, was used for spectral analysis and plotting of the graphs. It was also used for finding root mean square (RMS) voltage plots and fitting curves for determining mathematical models to be used in a computerized real time, degree of motion sickness indicator (5).

Electrocardiogram

The heart rates of 16 subjects were measured by counting the beats in 20 second time slots during 7 symptom periods: control, each of four levels severity, frank sickness (just prior to emesis), and post emesis (just after emesis). The results are presented in table 3.

Table 3.

Heart Rates (beats/minute)

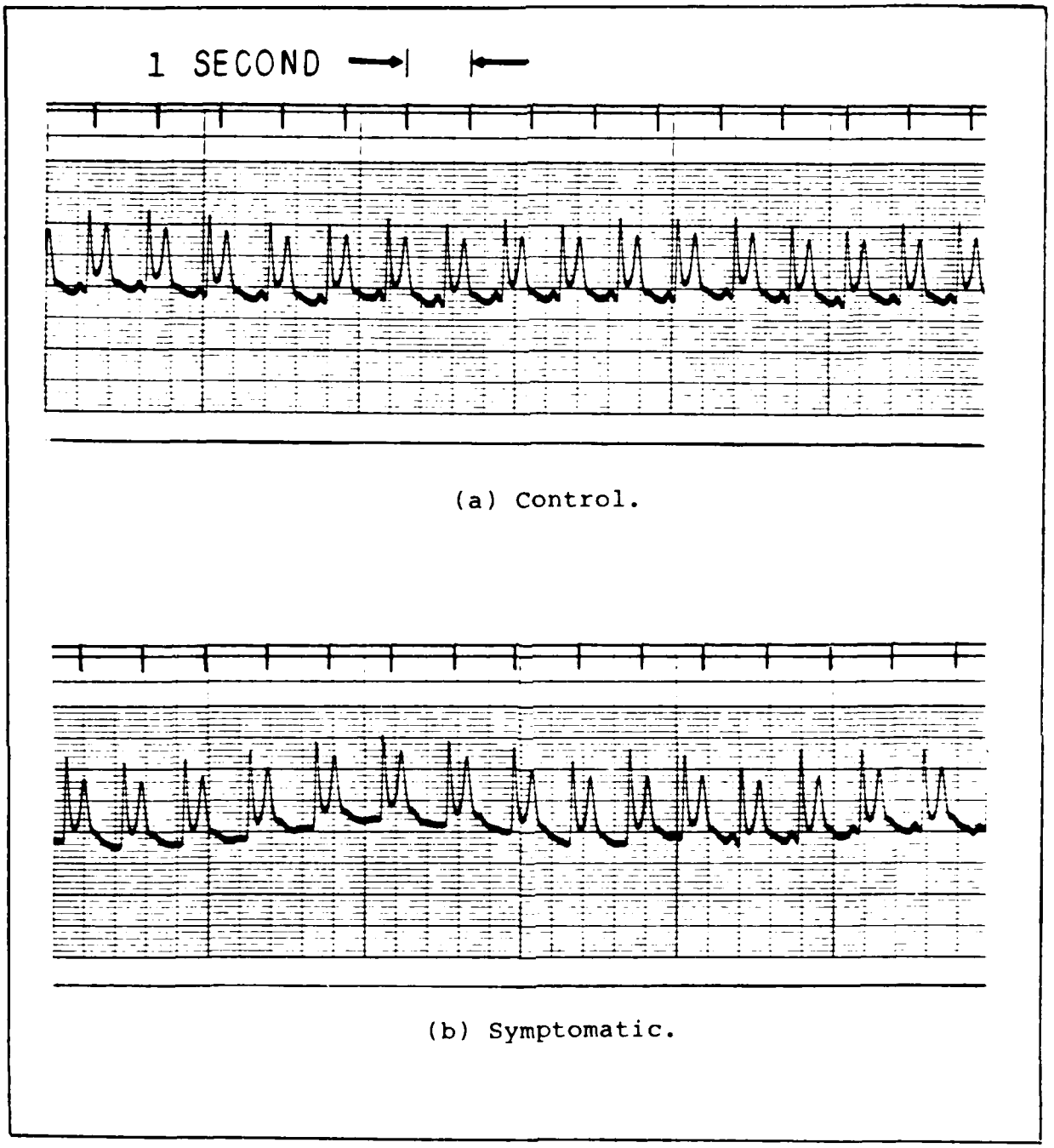
		Level of Severity					
Subject Number	Control	M I	M IIB	M IIA	M III	Frank Sickness	Post Emesis
1	66	69	72	81	79	66	84
2	60	69	63	75	99	81	66
3	66	72	81	90	87	75	87
4	63	90	81	90	90	72	87
5	63	69	75	63	78	69	99
6	66	93	93	102	96	90	90
7	51	72	69	75	102	90	96
8	69	75	69	69	72	63	66
9	66	78	84	78	87	87	87
10	75	105	105	120	120	87	99
11	54	75	75	75	69	75	78
12	90	87	93	102	114	102	99
13	81	93	96	99	105	114	108
14	57	96	90	84	93	93	75
15	63	63	69	78	72	78	75
16	60	90	112	99	99	87	69
Average	66	81	83	86	91	83	85

The most obvious trend was the heart rates tend to increase as motion sickness evolves for everyone in the population. Rate changes vary widely for different people; however, most of the population in table 3 can be classified into two groups. The rates for subjects 1, 3, 4, 5, 7, 8, and 10 all slowed during frank sickness and speeded up afterwards; whereas for subjects 2, 6, 12, 13, 14, 15, and 16 the rates either slowed during frank sickness and did not speed up again, or they slowed after emesis. The average rates are similar to those reported in the previous year, taking into account the differences in data and processing. Last year, the average rate during the control period was higher, causing shifts in all periods, and the symptom periods that the data were averaged over were slightly different, causing nonsymmetrical results (9:69-70).

During the 1986 research effort, the researchers also reported three cases of sinus arrest (9:70). This year only only subject five in table 3 experienced it. Samples of his electrocardiogram are shown in Fig. 3. This arrhythmia occurred several times during the recuperating period but not during the experiment, and unlike the previous year, the subject's heart rate did not decrease significantly indicating a nodal (i.e. junctional) response.

Electroencephalograms

Three electroencephalographs with two subdermal electrodes each were used during the experiments. Some low frequency (on the order of 0.1 Hz) signals were noted;



(a) Control.

(b) Symptomatic.

Fig. 3 Post Experimental Sinus Arrest.
Note that the width of the QRS complex
is nearly the same after the sinus block.

however, only one subject had signals with similar amplitudes to those reported during the previous year (16:56). More evidence of low frequency, high amplitude brain wave activity was found in the electronystagmograms discussed by Drylie (3).

Electroencephalograms on 10 subjects showed bursts of prominent alpha waves, most were slowed in frequency. These bursts ranged from 3 to 10 Hz: 1 sample at 10 Hz, 3 samples at 8 Hz, 1 sample at 7 Hz, 2 samples at 5 Hz, 1 sample at 4 Hz, and 2 samples at 3 Hz. Electroencephalogram plots taken during control and symptomatic periods with electrodes placed in the left frontal and left temporal areas are shown in Fig. 4. The prominent burst is between 3 and 4 Hz and its power spectrum is shown in Fig 5. Normal alpha activity at frequencies between 8 and 13 Hz occurs in awake relaxed adults with their eyes closed (8:675). The slower frequencies exhibited in 6 of the samples suggest hypocapnia, the shortage of carbon dioxide in the blood. The slowing caused by hypocapnia does not usually have marked changes in adults but is subject to much individual difference (19:179-180). More evidence of hyperventilation was found in the pneumograms.

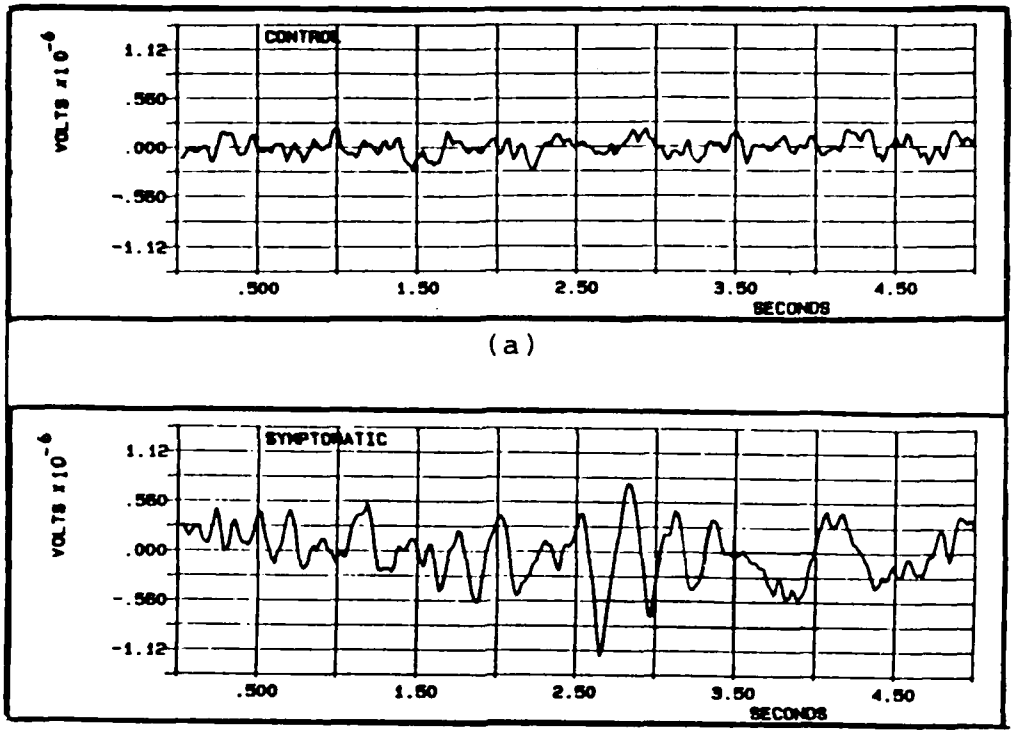


Fig. 4 Sample of Slowed Alpha Wave Activity.

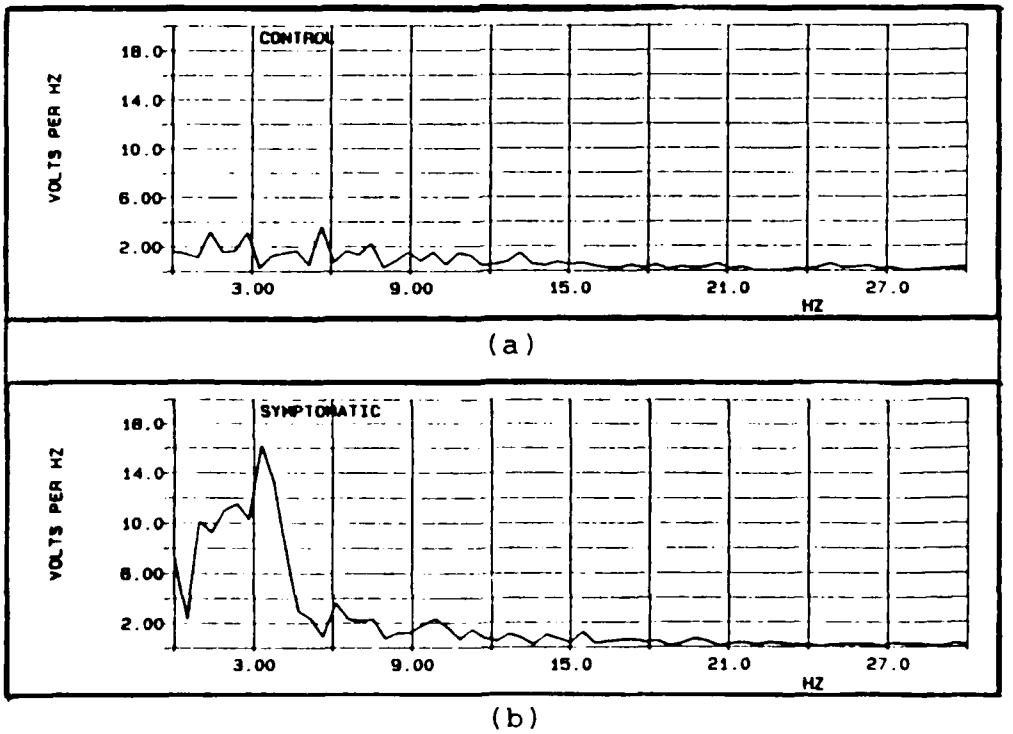


Fig. 5 Spectrum of Fig. 4.

Pneumograms

Two types of respiration were measured, thoracic and diaphragmatic. Only thoracic respiration was used in the analysis (see Chapter 5: Recommendations: Diaphragmatic Respiration). During the evolution of motion sickness, the amplitudes of the respiratory signals increased for all subjects tested. Fig. 6 shows the respiratory excursions for one subject over a 220 second period with levels of severity below.

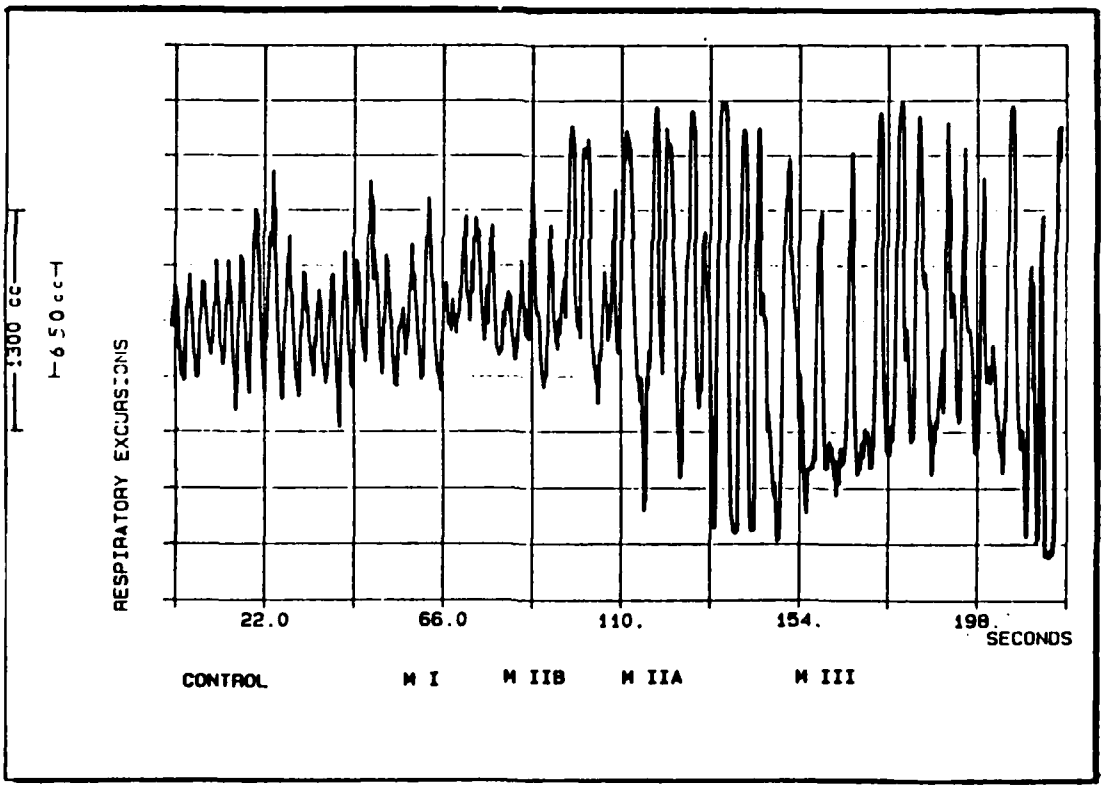


Fig. 6 Sample Pneumogram.

The increase in amplitude indicates hyperventilation while slow oscillatory shifting of the excursions from the

center line of the graph show long term thoracic capacity variations due to held expansions. Both phenomena are apparent in average power spectrums from 12 subjects shown in Fig 7. These power spectrums were calculated over 26 second

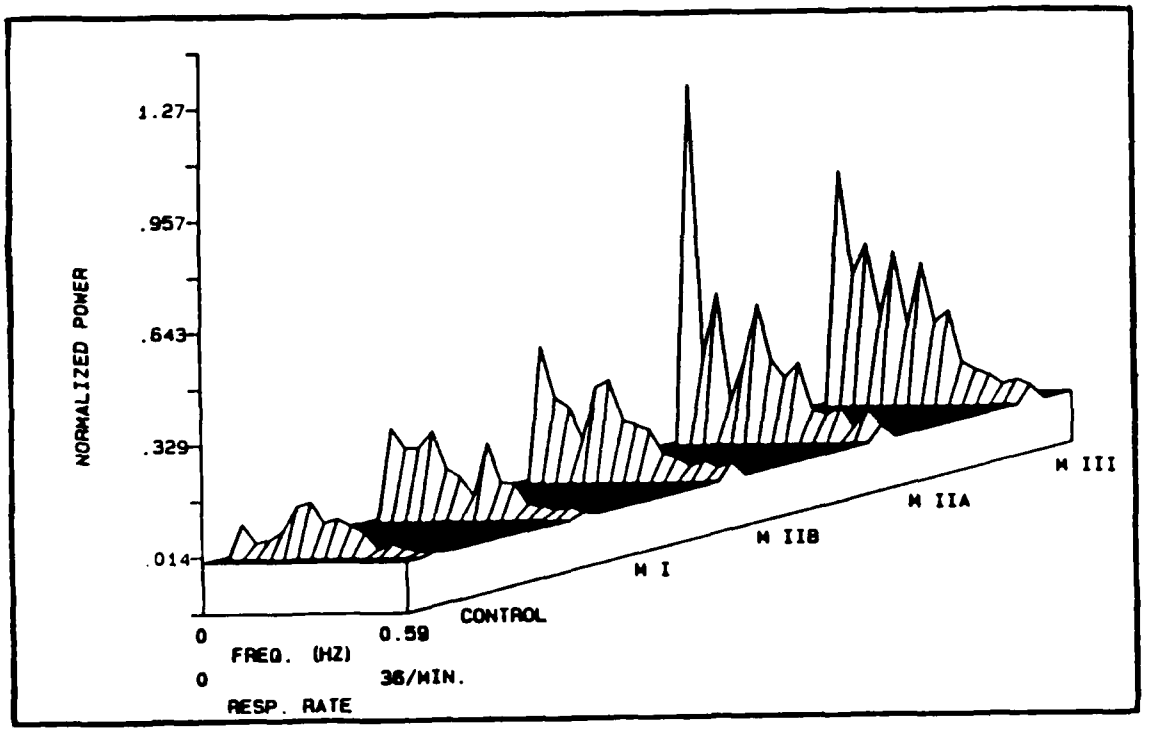


Fig. 7 Average Power Spectrum of Pneumograms from 12 Samples.

periods during control and 4 levels of severity. The total power in each spectrum increases as the level of severity increases. The large amplitude low frequency components during malaise are caused by held expansions of the thoracic cavity. The mean respiration rate reduced from 15 breaths per minute to about 12 during the onset of motion sickness.

These rates were computed as follows:

$$M = \frac{\sum_{i=1}^{N} A_i * F_i}{\sum_{i=1}^{N} A_i} \qquad (1)$$

where

M = mean frequency of respiration (Hz)

A = amplitude of component i (normalized)

F = frequency of component i (Hz)

N = number of components in the spectrum

$$MR = M * 60 \qquad (2)$$

where

MR = mean respiration rate (breaths per minute)

The mean and peak frequency components can be seen in table 4. Larger amplitudes in the power spectrum as sickness

Table 4.

Respiration Means and Peaks

Level of Severity	Mean		Peak	
	(Hz)	(breaths/minute)	(Hz)	(breaths/minute)
Control	0.25	15.0	0.23	14.0
M I	0.20	12.0	0.04	2.4
M IIB	0.21	13.0	0.04	2.4
M IIA	0.19	11.0	0.04	2.4
M III	0.20	12.0	0.04	2.4

increases signify deeper breaths. Since the intake volume increases but the subjects physical activity remains low, hyperventilation results.

Hyperventilation reduces the percentage of carbon dioxide in the blood causing changes in pH levels (1). This change may explain tingly sensations in the extremities often reported by AFIT subjects during motion sickness.

Splanchnograms

Splanchnogram is the generalized term for measurements over the gastro-intestinal track, which included electric and sound measurements. Two electrosplanchnograghs, which consisted of two electrodes each, were used in the experiments. One sensor used electrodes placed over the duodenum and over the right lower quadrant of the abdomen. The other sensor used electrodes placed over the lower stomach and the left lower abdomen. Only the former is discussed because the measurements were similar.

An example of an electrosplanchnogram is shown in Fig. 8. The levels of severity are shown below. The graph shows a typical increase in amplitude as sickness becomes more severe. The greatest increase occurs during M IIA and M III. Fig. 9 shows an average power spectrum from 12 electrosplanchnograms for each level of severity. The spectrums were calculated over 26 second periods covering each level of severity, and all the spectrums were normalized by dividing by the peak amplitude in the M III spectrum. The peak amplitude in the M III spectrum is approximately 14

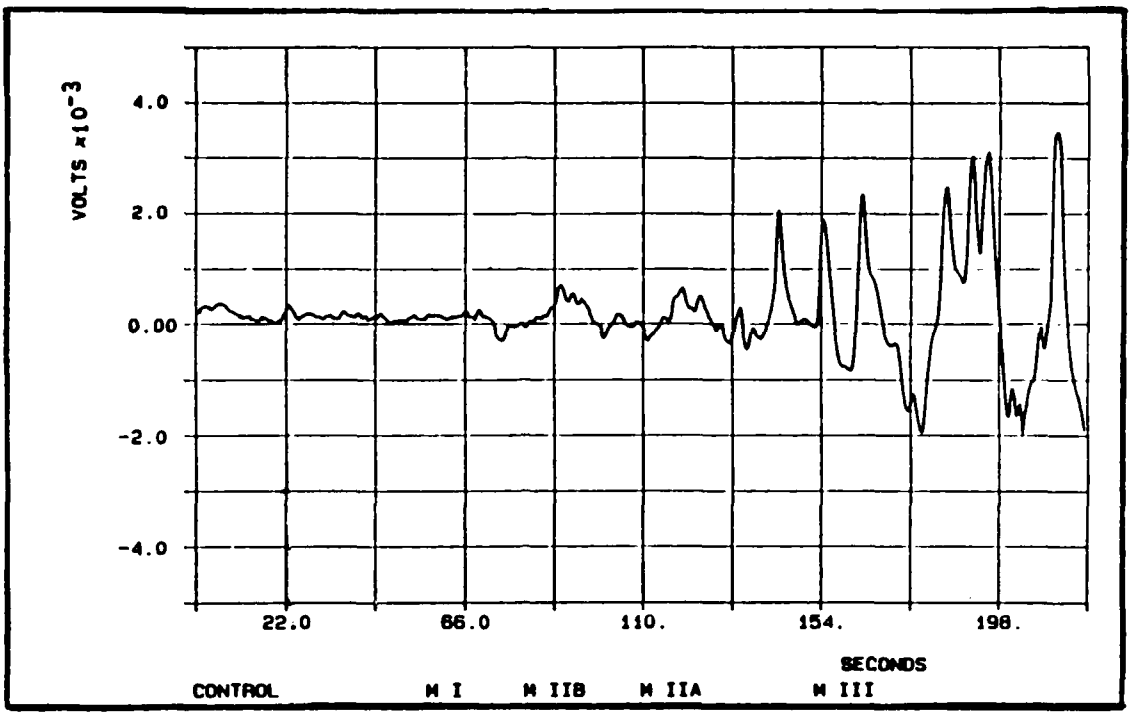


Fig. 8 Sample Electrosplanchnogram.

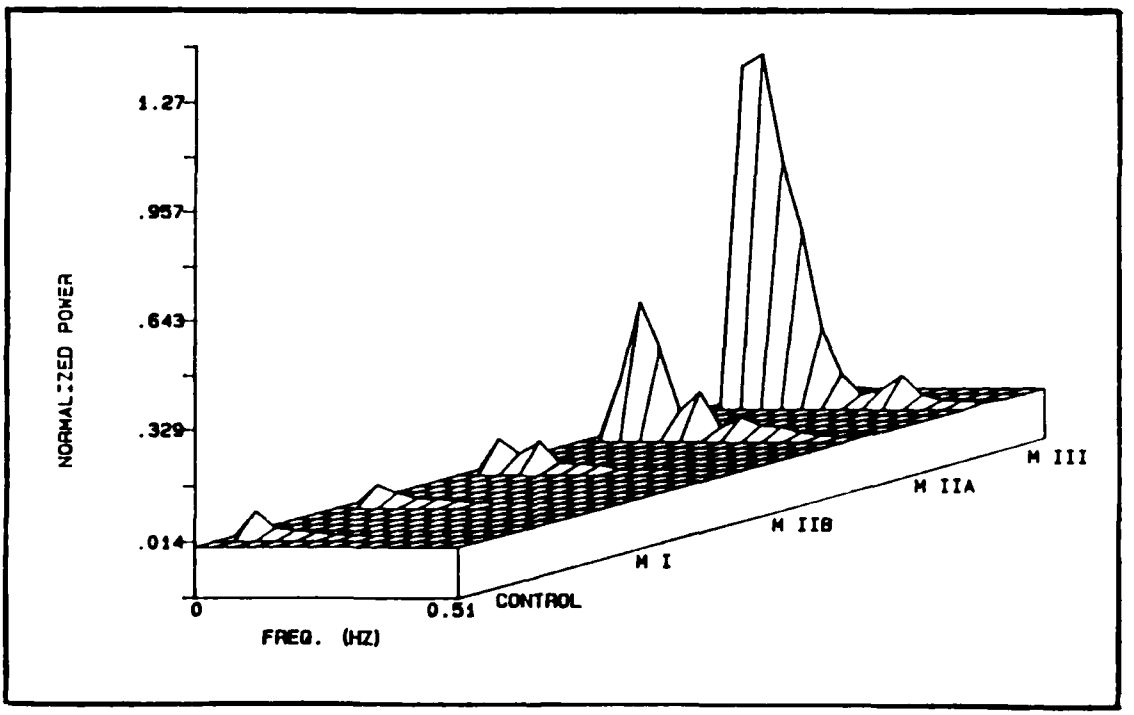


Fig. 9 Average Power Spectrums of Electrosplanchnograms from 12 Samples.

times that of control. Along with the dramatic amplitude changes, the frequency means and peaks also changed as seen in table 5. The frequency means were computed using equation (1), and the basic electrical rhythms (BER) were found by multiplying the frequency peaks by 60.

Table 5.

Electrosplanchnogram Means and Peaks

Level of Severity	Mean (Hz)	Peak (Hz)	BER (cycles/min.)
Control	0.09	0.04	2.4
M I	0.10	0.04	2.4
M IIB	0.11	0.04	2.4
M IIA	0.13	0.08	4.8
M III	0.11	0.08	4.8

Phonosplanchnograph recordings revealed a decrease in gastro-intestinal noise during the evolution of motion sickness for all subjects tested. The noise reduction verifies that mechanical activity decreases as the frequency of the electrical activity increases in the gastro-intestinal track. The increase of BER is a pathological condition also known as tachygastria. Stern found that it can result from motion sickness (21). Tachygastria can affect intestinal peristalsis similar to the way cardiac arrhythmias affect normal heart operations (1).

Photo-plethysmogram

As discussed earlier, technical problems with the photo-plethysmographs prohibited collection of good data for most of the thesis effort. One of two good plethysmograms recorded is shown in Fig. 10. The signal was digitally

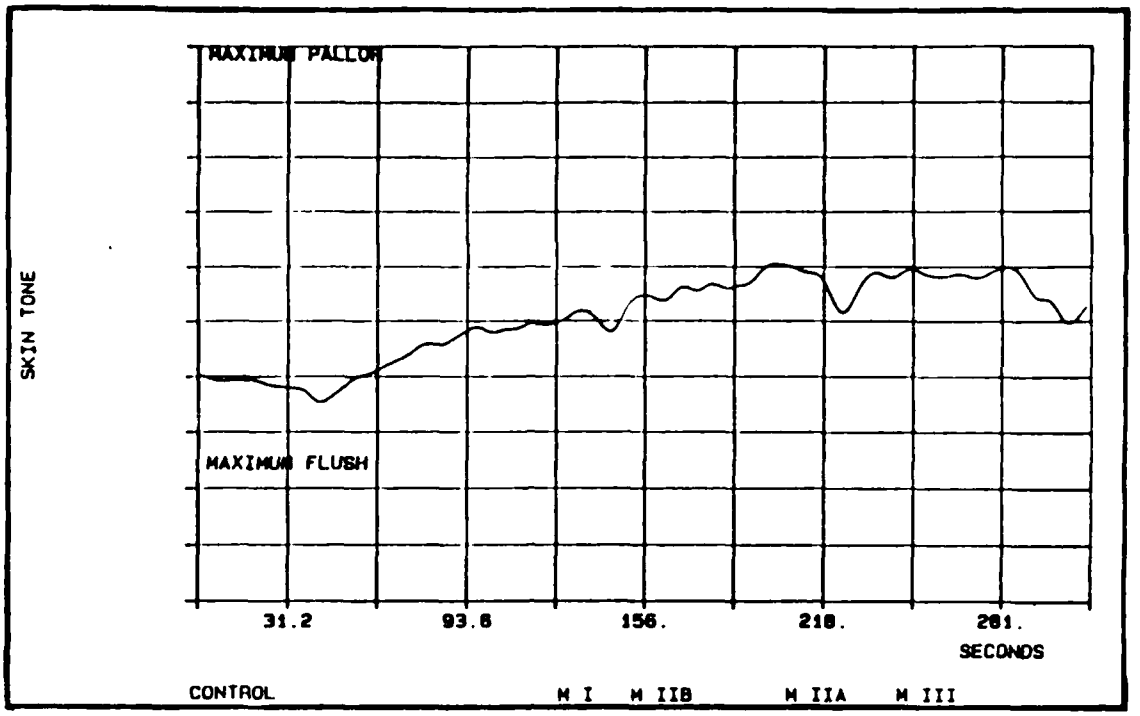


Fig. 10 Sample Photo-plethysmogram. Calibration values for maximum skin flush and pallor are shown on the graph.

filtered with a 0.15 Hz low pass filter to reduce noise, and the maximum flush and pallor levels determined in the calibration (see appendix C) are shown. The graph clearly shows a gravitation towards pallor as the Coriolis stimulus persists. This corresponds to the visual observation of the subject. A plethysmogram on another subject yielded similar results.

V. Conclusions and Recommendations

Conclusions

The AFIT motion sickness lab equipment and procedures are very effective for conducting basic research on motion sickness. Much data were recorded and analyzed; consequently, the physiological effects of the disorder are better understood. In addition, the knowledge of what happens to several physiological parameters during the evolution of motion sickness allowed for the development of computerized motion sickness indicators (5).

Several conclusions were reached about the experiment from the data analyzed here.

Cardiogram. The electrocardiogram revealed increasing heart rates for all subjects during the evolution of motion sickness. This implies that increased cardiac rhythms are a symptom of motion sickness. Also most subjects experienced a decrease of heart rate during the frank sickness period. Although the decrease was slight as compared to the decrease three subjects experienced during the previous year (9:69-70), it is relevant and its cause should be further investigated.

Encephalograms. Some evidence of the high amplitude, low frequency brain wave activity found during the previous year was noted, but by no means were these results confirmed. The subdermal electrodes used in this series of experiments eliminated the possibility of artifactual signals

being caused by sweat. Some low frequency signals were found, but only data from one subject resembled the activity found during the previous year.

A new finding this year was that alpha wave frequencies slowed to as low as 3 Hz in some subjects. Most of the alpha bursts were noted late in the experiment, and often after head movements were terminated. This brain wave activity may be caused by hyperventilation.

Pneumograms. The pneumograms revealed that although respiratory rates change little, the volumes sometimes tripled during severe motion sickness, resulting in hyperventilation.

Splanchnograms. The splanchnograms revealed large increases in intestinal electrical activity with decreases in mechanical activity during severe motion sickness.

Plethysmographs. Problems in the past with photoplethysmographs invalidated most data recorded. Recent improvements in the sensors and the procedures allowed for two sets of good data to be recorded. The data showed both subjects becoming more pale, especially during severe malaise. Visual observations confirmed the data. With more data from the improved plethysmographs, facial pallor can be used as a motion sickness indicator.

Recommendations

Pitch and Roll Controls. In the multi-axis rotating chair, the slip rings once used for pitch and roll control channels are presently used for data channels. Since the

pitch and roll are disabled, the subject must perform head movements to elicit a motion sickness response. Any bodily movements increase the likelihood of noise and sensor malfunction.

It is recommended that the pitch and roll controls be re-established and used in placed of head tilts during motion sickness experiments.

Voice Data. Voice data are transmitted via a radio microphone and received on a portable receiver. Much electronic equipment in the lab causes radio frequency interference that degrades the voice quality, often making the recording unintelligible.

It is recommended that a voice channel be established over the slip rings to provide a clear signal.

Biofeedback. As part of the thesis project, a motion sickness indicator was developed (5). This indicator can be displayed in the multi-axis rotating chair using available hardware.

It is recommended that the indicator be implemented in the chair and a biofeedback treatment be developed and tested.

Multiplexing of Data and Control Channels. All of the slip ring channels in the multi-axis rotating chair are presently being used for data or control. Since no more channels are available, new implementations using one or more slip ring channels are possible only at the expense of present ones.

It is recommended that a multiplexer system be implemented on some of the slip rings to increase the number of available channels for control, voice, data, and biofeedback signals.

Bearings. Late in the experimental stages of this thesis project, the plastic ball bearings in the multi-axis rotating chair had to be replaced. Grease had not been applied to them for over a year, and they were dry.

It is recommended that a preventive maintenance program be established to grease the bearings approximately once a month.

Data Signals and Noise. During motion sickness experiments, physiological signals in the microvolt and millivolt range are amplified and recorded. Inevitably, noise is also recorded. Noise can be caused by motion and sweat artifacts, cross talk, ground loops, AC power coupling, and any electrically powered equipment. As discussed in chapter 2, steps were taken to eliminate some noise such as that from sweat artifacts and AC power coupling; however, other types such as those induced by motion still can be observed in some data. The sensors on the head were most susceptible to motion produced noise because of the head motion required during the experiment.

It is recommended that a study of noise sources be accomplished so that unusual signals can be clearly distinguished as either physiological in nature or noise related. Deterministic signals of similar levels and

frequencies to the physiological signals of concern can be used to determine overall system noise in each circuit. The circuits can be tested for motion artifacts and cross talk by fully instrumenting a subject and having him perform head movements while sitting in the idle multi-axis rotating chair.

Diaphragmatic Respiration. The sensor used to measure diaphragmatic expansions also inherently measured thoracic expansions. Since the two measurements correlate highly, pure diaphragmatic data could not be obtained. In addition, the placement of the diaphragmatic sensor could not be standardized for all subjects because of varying body sizes and conflicts with other body sensors.

It is recommended that a new sensor be developed that will not measure thoracic expansions along with diaphragmatic. One way of accomplishing this, suggested by Dr. Czelen, may be to use a sensor similar to the present one with the exception of not using a circumferential strap around the subject. Instead, attach the strap ends to each side of the rib cage using some adhesive material. Electrodes may suffice because they have both a strong adhesive and a knob to which the ends of the strain gauge strap can be attached. The strain gauge can then be located directly over the upper abdomen so that diaphragmatic expansions can stress it, but thoracic expansions will not.

Carbon Dioxide Sensor. Both electroencephalograms and pneumograms showed strong evidence of some degree of

hyperventilation in all subjects. Hyperventilation can be quantified by measuring the amount of carbon dioxide in the blood (1).

It is recommended that a carbon dioxide sensor be acquired, and the extent of hyperventilation studied further and incorporated in the overall study of motion sickness.

Appendix A: Motion Sickness Protocol and Questionaire

1. Title: Motion Sickness: A Study of its Etiology and A Statistical Analysis.

2. Principal Investigator: William Czelen, M.D.; 255-5276; AFIT/ENG.

   Associate Investigators: Matthew Kabrisky, Ph.D.; 255-5276; AFIT/ENG.

   Captain Edward Fix; 255-5533; AFIT/ENG.

   First Lieutenant Michael Drylie; 255-5533; AFIT/ENG.

   First Lieutenant Pierre Gaudreault; 255-5533; AFIT/ENG.

3. Date: 20 July 1987 Type: Facility Renewal: Yes

4. Synopsis:

   The objective of this research is to investigate the causes of motion sickness, to refine a predictive model based on physiological parameters, and to develop a real-time computer prediction program. The research will expand on work done by previous researchers (Levy, Jones, & Carlson, 1981; Lackner & Graybiel, 1983; etc.). This research will simultaneously measure at least 16 parameters by using a system developed by researchers at the Air Force Institute of Technology (Earl & Peterson, 1983; Fitzpatrick, Rogers, & Williams, 1984; Jarvis & Uyeda, 1985; Hartle, McPherson, & Miller, 1986).By measuring this many physiologic variables at once, it is hoped that the extremely complex physiologic interrelationships involved in motion sickness symtomatology can be more easily studied and analyzed.

5. Summary of last year's experience:

   During the period from August 1986 through July 1987, over 30 motion sickness experiments were performed. Several parameters and their instrumentation were upgraded or added (new equipment and procedures are documented herein). Data collection proceeded according to plan and was unremarkable. With the exception of a few cases of notable but controlled

bradycardias (slowed heart rhythm) which quickly resolved, all procedures and subjects' responses were without incident.

During the past year notable progress has been made in quantifying many of the physiologic responses we have been measuring. We have also begun a more comprehensive investigation into several novel responses we have observed that may hold promise for original forms of pharmacologic therapy.

6. Attachments: Protocol Curriculum Vitae
Consent Form
Addendum to Consent Form
Medical Examination Form

AFIT/EN Research Protocol

I. IDENTIFICATION

1. Title: Motion Sickness: A Study of its Etiology and A Statistical Analysis.

2. Date: 10 Feb, 1987

3. Project/Task/Work Unit: N/A

4. Principal Investigator: William Czelen, M.D.; 255-5276; AFIT/ENG.

5. Associate Investigators: Matthew Kabrisky, Ph.D.; 255-5276; AFIT/ENG.

Captain Edward Fix;255-5533; AFIT/ENG.

First Lieutenant Michael Drylie; 255-5533; AFIT/ENG.

First Lieutenant Pierre Gaudreault; 255-5533; AFIT/ENG.

6. Medical Consultant: Colonel Charles Hatsell M.D.; USAF/MC.

II. RESEARCH BASIS

1. Objective

a. To investigate and quantify motion sickness symptoms in an attempt to predict the onset of those symptoms and provide the basis for a biofeedback parameter for treatment.

b. To more extensively characterize specific organ system dysfunction to permit identification of alternative chemotherapeutic treatments.

2. Background and Relevance

Previous research suggests there are relationships between the onset of motion sickness symtomatology and specific measurable physiological criteria. In 1986, Hartle, McPherson, and Miller recorded up to

16 physiological parameters and made a predictive model based on them with some success. We propose to collect data from more subjects, extend and improve the predictive model, and incorporate it into a real-time predictive computer program. While it appears there is not one parameter that accurately portrays the amount of discomfort for the individual, there is hope that a proper combination of parameters might give a reliable enough indicator to use as a biofeedback parameter.

3. Experimental Plan

a. Equipment and Facilities

(1). All experimental test sessions and data collection will be conducted in the AFIT Engineering Building 640, room 150.
(2). All experiments will consist of a test subject performing head movements in a rotating chair. The required head movements are recorded on a small portable tape recorder and require the subject to make a head movement every 10 seconds.
(3). Overall, the following equipment will be used:

(a). Equipment-subject interface:

1. Rotating chair for eliciting the motion sickness response.
2. Chair speed control console.
3. Electrodes:
   a. Meditronic Medical "Huggables" Infant Monitoring Electrodes.
   b. NDM silver/silver chloride electrodes.
   c. Subdermal EEG electrodes.

   (Note: all sensors and electrodes connect through 100K to 1 Meg ohm isolation resistors to 12-volt battery powered amplifiers and processing circuitry. The data passes through slip rings to data recording equipment.)

4. Safety belt in the rotating chair.
5. An Astropulse 90 Blood Pressure Cuff to record arterial blood pressure.

6. Two pneumographs used to measure respiration (both abdominal and thoracic). The pneumographs are circumferential belts that employ strain gauges to detect respiration rate and depth changes. (Note: the pneumographs are electrically isolated from the subject.)
7. Two thermistors for measuring skin temperature.
8. Two GSR electrodes for measuring skin conductance.
9. Two plethysmographs for measuring blood flow volume (pallor). They are photo transistors, resistors, and an LED mounted in an epoxy housing. One is attached to the index finger and the other to the subject's cheek. Both plethysmographs are self-adhesive.
10. A phonosplanchnograph for a record of audible gastrointestinal mechanical activity.
11. A wireless FM microphone to allow the subject's symptom reports to be recorded along with the physiological data.
12. A contingency motion sickness bag of the type issued to Air Force aircrews and passengers.
13. An Ace elastic bandage and manual blood pressure cuff for pallor calibration.

(b). Recording equipment:

1. Soltec model 8k26 16 channel strip chart recorder.
2. A Kyowa Dengyo RTP-610A 14 channel FM data recorder.
3. An Ampex FR 1300 14 channel FM data recorder.
4. A Zenith 248 computer will be used for statistical data analysis and real time evaluation.

b. Method

As much as possible, each experiment will be standardized and follow an identical approach. The first step of the experiment will entail the human volunteer filling out a Medical History Questionnaire, an AFIT Motion Sickness Questionnaire, and a Subject Consent Form. In addition, each subject will receive both a written and oral briefing describing what he/she can expect to experience during the experiment, as well as have any questions answered.

The second step of the experiment will consist of a standard medical examination by the attending physician, Dr. William Czelen, to determine each subject's physical capability to participate in the experiment. Once the subject's exam is complete, and no problems noted, the subject's forearm and hand are tightly wrapped with an elastic bandage to exsanguinate the region, a blood pressure cuff is then inflated around the forearm to above 200 mm. Hg. for approximately one or two minutes--a period too short for any clotting danger or more than mild discomfort. This provides for the quantitative calibration of pallor measurements. Next the subject will have silver/silver chloride type electrodes attached. Parameters to be studied will be electrocardiogram, electroencephalogram, galvanic skin response, pulse rate, blood pressure, electronystagmogram, electrosplanchnogram, temperature, respiration, and skin pallor. Prior to each sensor's placement, the area will be vigorously scrubbed with alcohol pads to remove the outermost epidermal layer and oil to ensure a good electrical contact. Once all electrodes are in place, and the electrode leads attached, the subject will be assisted into the chair and then restrained by the safety belt. The subject's eyes will be taped closed and covered to prevent any extraneous visual stimulus.

The third step in the experiment will be to spin the subject with the subject performing the head movements to elicit the motion sickness response. The chair will initially spin at a rate of 14 revolutions per minute. The subject's vital signs will be allowed to stabilize for approximately one minute before performing any head movements. When the movements start, the subject will be instructed

to tilt the head to the left, right or forward, and back upright. The head motions will normally continue until motion sickness symptoms are fully evolved. The subject's physiological state will be constantly monitored, and the subject will be asked for verbal inputs on his/her condition. If the subject shows no signs of motion sickness after two minutes, the chair speed will be increased by two RPM every two minutes until the chair's maximum speed of 30 RPM is reached. If there is no response after 20 minutes, the experiment will be terminated.

Upon the subject's request to stop the experiment, the chair will be decelerated at a rate of approximately five RPM per minute to avoid any additional provocative stimulus. After the chair has come to a complete stop, the subject will remain seated until all physiological indicators return to a state near the pretest values. All power will be removed from the chair to prevent accidental rotation. After the subject stabilizes, the blindfold will be removed and the subject will be assisted from the chair. All electrodes will be removed and the subject will be interviewed for any comments about the experiment. With the approval of the physician, the subject will be released.

c. Subjects

Subjects will be recruited using personal contact and publicity. Both military members and civilian Air Force employees will be chosen. We hope to attract a wide range of test subjects. Most subjects will participate only once, but those who volunteer to run a second time may be run again at least one month later. We will run up to 30 subjects, although the total number of subjects run will depend on the number of volunteers we receive.

Before undertaking a full test of the subject's motion response, a susceptibility test will be performed. The susceptibility test is a simple procedure consisting of two parts. In the first part, the volunteer is briefed on what to expect, how to perform head movements, and how to rate symptoms. In the second part, the volunteer mounts the chair and is blindfolded. The chair is

then rotated at 14 RPM and the volunteer is given the same head movement commands used in the experiment. The subject is constantly queried as to the symptoms he/she is feeling. The test is terminated when the subject becomes nauseated or after 5 minutes. If the volunteer is not nauseated in 5 minutes he/she is not considered to be a suitable subject for the experiment.

d. Reporting

All test data will be associated with the subject's name, but any publication of the data will not reveal the name or any other information about the subject. Data will not be available to anyone but the investigators. Upon request, subjects will be told about general results of the study, and will be shown the results of their particular test session.

e. Schedule
Experiments will begin upon protocol approval and all data should be collected by August 1988.

f. Data analysis
The data will be analyzed by a variety of statistical means including analysis of variance (ANOVA) and time series analysis.

III. Medical Risks, Safety Precautions, and Measures

This research using human subjects places the subjects at minimal risk in accordance with the definition of risk in AFR 169-3. Standard medical histories are taken and relevant physical evaluations are administered prior to each experiment.

No history of subject harm has ever been reported in previous studies. As part of the initial informed consent briefing, subjects will be assured that if discomfort or displeasure is experienced, they are free to terminate the experiment without prejudice.

All physiologic sensors are powered by 12 volt batteries regulated to +/-5 volts. All electrodes with direct electrical contact with the subject are isolated from the signal processing instrumentation by 100 kilohm to 1 megohm resistances.

The platinum subdermal electroencephalographic electrodes are the standard type used in clinical

neurology practice. They are both heat and alcohol sterilized between uses to obviate infection and contagion. The discomfort upon insertion is momentary and mild.

The motion chair has been man rated and used safely over the years in previous studies. Further, only the planetary component of rotation in the yaw direction is used eliminating risk from tilting or rolling. The subject is secured with a seat belt.

Finally, as part of the calibration procedure before an experiment, the subject's forearm and hand are tightly wrapped for approximately a minute with an elastic bandage to exsanguinate the region--a period too short for any clotting danger or more than mild discomfort.

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PROTOCOL CURRICULUM VITAE

1. Name: William E. Czelen, M. D.
   Grade or Rank: N/A (contractor)
2. Current Position Title: Professor of Electrical Engineering/Clinical Instructor-Aerospace Medicine.

   Location: Air Force Institute of Technology/WSU-SOM. WPAFB, Ohio.
3. Education:
   B.S., Electrical Engineering, Carnegie-Mellon Univ., Pittsburgh, PA. 1971.
   B.S., Biology, University of Pittsburgh, Pittsburgh, PA. 1973.
   M.D., Temple University School of Medicine, Philadelphia, PA. 1979.
   M.S., Wright State University School of Medicine, Dayton, Ohio. 1987.

4. Relevant Experience:
   1985-1987: SENIOR RESEARCH ASSOCIATE-National Research Council/AFAMRL/AFIT.
   1986-1987: CLINICAL INSTRUCTOR-Wright State University Department of Community Medicine.
   1983-1985: RESIDENCY IN AEROSPACE MEDICINE-Wright State University Department of Community Medicine.
   1984-1986: PHYSICIAN-Wright State University/FAWCAC.
   1983-1985: EMERGENCY ROOM PHYSICIAN-Independent Contractor/Southwestern Ohio.
   1982-1983: GENERAL MEDICAL PRACTICE-Washington, DC.
   1982-1983: MEDICAL DIRECTOR-Consumer Medical Services-Manna Corp, Arlington, VA.
   1979-1981: RESIDENCY IN ANESTHESIOLOGY/CRITICAL CARE MEDICINE-Georgetown University Hospital, Washington, DC.
   1979: National Aeronautic and Space Administration-Johnson Space Center, Houston, TX.

5. Licensure: Doctor of Medicine-Ohio. 1983.
   Medicine and Surgery-D.C. 1980.
   Diplomate-National Board of Medical Examiners. 1980.

PROTOCOL CURRICULUM VITAE

1. Matthew Kabrisky, Ph. D.
   Grade of Rank: GM-15.
2. Current Position Title: Professor of Electrical Engineering.

   Location: Air Force Institute of Technology, WPAFB, Ohio.
3. Education:

   B. S., Electrical Engineering, Polytechnic Institute of Brooklyn, 1951.
   M. S., Electrical Engineering, Polytechnic Institute of Brooklyn, 1952.
   Ph. D., Electrical Engineering, University of Illinois, 1964.

4. Member of the Series of Biomedical Engineering Research Teams with AMRL since 1964.

5. *Licensure:* N/A.

PROTOCOL CURRICULUM VITAE

1. Name: Edward L. Fix
   Rank: Captain, USAF

2. Current Position: Student at the Air Force Institute of Technology; Graduate in Electrical Engineering.

   Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:

   B.S.; Electrical Engineering, Iowa State University, 1975

   M.S.; Electrical Engineering, Air Force Institute of Technology (May 1986 - Present).

4. Relevant Experience:
   Based on courses taken at AFIT since enrollment.

   Undergraduate Pilot Training, Jan - Dec 1979

5. Licensure: N/A.

PROTOCOL CURRICULUM VITAE

1. Name: Michael E. Drylie
   Rank: First Lieutenant, USAF

2. Current Position: Student at the Air Force Institute of Technology; Graduate in Electrical Engineering.

   Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:

   B.S.; Electrical Engineering, Ohio State University, 1983

   M.S.; Electrical Engineering, Air Force Institute of Technology (May 1986 - Present).

4. Relevant Experience: Based on courses taken at AFIT since enrollment.
5. Licensure: N/A.

PROTOCOL CURRICULUM VITAE

1. Name: Pierre J. Gaudreault
   Rank: First Lieutenant, USAF

2. Current Position: Student at the Air Force Institute of Technology; Graduate in Electrical Engineering.

Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:

   B.S.; Electrical Engineering, University of Southwestern Louisiana, 1983

   M.S.; Electrical Engineering, Air Force Institute of Technology (May 1986 - Present).

4. Relevant Experience: Based on courses taken at AFIT since enrollment.

5. Licensure: N/A.

THE PHYSIOLOGIC CHARACTERIZATION OF MOTION SICKNESS

SUBJECT CONSENT FORM

I, _____, am participating because I want to. The decision to participate in this research study is completely voluntary on my part. No one has coerced or intimidated me into participating in this program. _____ has adequately answered any and all questions I have asked about this study, my participation, and the procedures involved, which are set forth in the addendum to this Agreement, which I have initialed. I understand that the Principal Investigator or his designee will be available to answer any questions concerning procedures throughout this study. I understand that if significant new findings develop during the course of this research which may relate to my decision to continue participation, I will be informed. I further understand that I may withdraw this consent at any time and discontinue further participation in this study without prejudice to my entitlements. I also understand that the Medical Consultant for this study may terminate my participation in this study if he feels this to be in my best interest.

I understand that my entitlement to medical care or compensation in the event of injury are governed by federal laws and regulations, and that if I desire further information I may contact the Principal Investigator.

I understand that I will not be paid for my participation in this experiment.

I understand that my participation in this study may be photographed, filmed or audio/videotaped. I consent to the use of these media for training purposes and understand that any release of records of my participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations. This means personal information will not be released to an unauthorized source without my permission.

I FULLY UNDERSTAND THAT I AM MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

VOLUNTEER SIGNATURE AND SSAN DATE

WITNESS SIGNATURE DATE

ADDENDUM TO SUBJECT CONSENT FORM

VOLUNTEER BRIEFING

You are about to participate in a motion sickness study. In order for us to gather the data we need, you must attain the symptoms of motion sickness. We will attach physiological sensors (electrodes, bands, and adhesive sensors) and rotate you in a chair, gathering data on how your body reacts. You will control the major stimulus that will cause your symptoms by tilting your head out of the plane of rotation. Once motion sickness symptoms have fully evolved, or any time you desire, the experiment will be terminated. Once you stop all head movements, the symptoms will begin to abate.

Once you are positioned in the rotating chair, the only actions you will need to perform are executing the head movement commands, and reporting ANY and ALL SYMPTOMS you feel. You must perform every head movement that is ordered, until the experiment ends. Otherwise, please keep yourself (especially your hands and arms) as motionless as possible to keep from affecting the data. During motion sickness experiments, many people have a tendency to not want to talk; however, you must report your symptoms to us. If you do not communicate with us, we will periodically ask you how you are feeling. In addition to specific symptoms such as normal, dizzy, tingly, tired, warm, cold, sweaty, nausea, or headache, please try to give a numerical value between 1 and 10 with 1 meaning you feel good and 10 meaning you are about to vomit. Since you will feel sick during the experiment, you may be tempted to fight the sensations. PLEASE DO NOT RESIST ANY SYMPTOMS. Doing so may influence the accuracy of our data. Just relax and let whatever happens happen. You will be the one to end the experimental run. To end it, tell us and do not move your head again as we stop the chair.

No one has ever been injured in these experiments. You may feel wrung out for the rest of the day, and should plan your activities accordingly. Rarely, a subject may experience queasiness and lethargy for up to 24 hours after the test. Finally, some subjects show markedly slowed heart rhythm as they become very ill. This condition always disappears as the stimulus is removed.

The experiment, including preparation time, will last approximately 3 hours.

You may be photographed, filmed or audio/video taped for training purposes. Any release of records of your participation may only be disclosed according to federal law, including the Federal Privacy Act. This means personal information will not be released to an unauthorized person. Your name will be associated with your data in our files, but will not be published.

You will not benefit directly from this experiment. However, we hope that by learning more about motion sickness, we can increase aircrew training efficiency and save money and resources for the Air Force.

Ask any questions that occur to you. You can contact Dr. Kabrisky or Dr. Czelen at 255-5276 or Capt Fix at 429-2845.

_____

Volunteer Signature

PATIENT QUESTIONNAIRE

PATIENT'S NAME _____ BIRTH DATE _____ SEX _____ S. M. W. D.

ADDRESS _____ TEL. NO. _____

INSURANCE _____ REFERRED BY _____ OCCUPATION _____

INSTRUCTIONS: PUT ☑ IN THOSE BOXES APPLICABLE TO YOU AND IN THE "YES" OR "NO" SPACE. IF LINES ARE PROVIDED WRITE IN YOUR ANSWER.

FAMILY HISTORY

	FATHER	MOTHER	BROTHER				SISTER				SPOUSE	CHILDREN					
			1	2	3	4	1	2	3	4		1	2	3	4	5	6
AGE (IF LIVING)																	
HEALTH (G) GOOD (B) BAD																	
CANCER																	
TUBERCULOSIS																	
DIABETES																	
HEART TROUBLE																	
HIGH BLOOD PRESSURE																	
STROKE																	
EPILEPSY																	
NERVOUS BREAKDOWN																	
ASTHMA, HIVES, HAYFEVER																	
BLOOD DISEASE																	
AGE (AT DEATH)																	
CAUSE OF DEATH																	

PERSONAL HISTORY

HAVE YOU EVER HAD . . .	NO	YES	HAVE YOU EVER HAD . . .	NO	YES	HAVE YOU EVER HAD . . .	NO	YES
☐SCARLET FEVER ☐SCARLATINA			☐ GONORRHEA ☐SYPHILIS			ANY ☐BROKEN ☐CRACKED BONES		
DIPHTHERIA			ANEMIA			RECURRENT DISLOCATIONS		
SMALLPOX			JAUNDICE			☐CONCUSSION ☐HEAD INJURY		
PNEUMONIA			EPILEPSY			EVER BEEN KNOCKED UNCONSCIOUS		
☐PLEURISY			MIGRAINE HEADACHES			☐FOOD ☐CHEMICAL ☐DRUG POISONING		
UNDULANT FEVER			TUBERCULOSIS			EXPLAIN		
☐RHEUMATIC FEVER ☐HEART DISEASE			DIABETES					
ST. VITUS DANCE			CANCER					
☐ARTHRITIS ☐RHEUMATISM			☐HIGH ☐LOW BLOOD PRESSURE			ANY OTHER DISEASE		
ANY ☐BONE ☐ JOINT DISEASE			NERVOUS BREAKDOWN			EXPLAIN		
☐NEURITIS ☐NEURALGIA			☐HAY FEVER ☐ ASTHMA					
☐BURSITIS ☐SCIATICA ☐LUMBAGO			☐HIVES ☐ECZEMA					
☐POLIO ☐MENINGITIS			FREQUENT ☐COLDS ☐SORE THROAT			WEIGHT: NOW ONE YR. AGO		
BRIGHT'S DISEASE			FREQUENT ☐INFECTIONS ☐BOILS			MAXIMUM WHEN		

ALLERGIES

ARE YOU ALLERGIC TO . . .	NO	YES	ARE YOU ALLERGIC TO . . .	NO	YES	ARE YOU ALLERGIC TO . . .	NO	YES
☐PENICILLIN ☐SULFA DRUGS			ANY OTHER DRUGS			ANY FOODS		
☐ASPIRIN ☐CODEINE ☐MORPHINE			EXPLAIN			EXPLAIN		
☐MYCINS ☐OTHER ANTIBIOTICS								
☐TETANUS ☐ANTITOXIN ☐SERUMS			ADHESIVE TAPE			☐NAIL POLISH ☐OTHER COSMETICS		

SURGERY

HAVE YOU HAD REMOVED . . .	NO	YES	HAVE YOU HAD REMOVED . . .	NO	YES	HAVE YOU . . .	NO	YES
TONSILS			☐OVARY ☐OVARIES			HAD HERNIA REPAIRED		
APPENDIX			HEMORRHOIDS			HAD ANY OTHER OPERATIONS		
GALL BLADDER			EVER HAVE A TRANSFUSION . . .			BEEN HOSPITALIZED FOR ANY ILLNESS		
UTERUS			☐ BLOOD ☐PLASMA			EXPLAIN		

X-RAYS

HAVE X-RAYS OF . . .	NO	YES	DATE	DISEASE PRESENT
CHEST				
☐STOMACH ☐COLON				
GALL BLADDER				
EXTREMITIES				
BACK				
OTHER				

HISTACOUNT CORPORATION, MELVILLE, N. Y. 11746

SYSTEMS

DO YOU NOW HAVE OR HAVE YOU EVER HAD . . .	NO	YES	DO YOU NOW HAVE OR HAVE YOU EVER HAD . . .	NO	YES
ANY ☐EYE DISEASE ☐EYE INJURY ☐IMPAIRED SIGHT			KIDNEY ☐DISEASE ☐STONES		
ANY ☐EAR DISEASE ☐EAR INJURY ☐IMPAIRED HEARING			BLADDER DISEASE		
ANY TROUBLE WITH ☐NOSE ☐SINUSES ☐MOUTH ☐THROAT			BLOOD IN URINE		
FAINTING SPELLS			☐ALBUMIN ☐SUGAR ☐PUS ☐ETC. IN URINE		
CONVULSIONS			DIFFICULTY IN URINATION		
PARALYSIS			NARROWED URINARY STREAM		
DIZZINESS			ABNORMAL THIRST		
HEADACHES: ☐FREQUENT ☐SEVERE			PROSTATE TROUBLE		
ENLARGED GLANDS			☐STOMACH TROUBLE ☐ULCER		
THYROID ☐OVERACTIVE ☐UNDERACTIVE ☐ENLARGED			INDIGESTION		
ENLARGED GOITER			☐GAS ☐BELCHING		
SKIN DISEASE			APPENDICITIS		
COUGH ☐FREQUENT ☐CHRONIC			☐LIVER DISEASE ☐GALL BLADDER DISEASE		
☐CHEST PAIN ☐ANGINA PECTORIS			☐COLITIS ☐OTHER BOWEL DISEASE		
SPITTING UP BLOOD			☐HEMORRHOIDS ☐RECTAL BLEEDING		
NIGHT SWEATS			BLACK TARRY STOOLS		
SHORTNESS OF BREATH ☐EXERTION ☐AT NIGHT			☐CONSTIPATION ☐DIARRHEA		
☐PALPITATION ☐FLUTTERING HEART			☐PARASITES ☐WORMS		
SWELLING OF ☐HANDS ☐FEET ☐ANKLES			☐ANY CHANGE IN APPETITE ☐EATING HABITS		
VARICOSE VEINS			☐ANY CHANGE IN BOWEL ACTION ☐STOOLS		
EXTREME ☐TIREDNESS ☐WEAKNESS			EXPLAIN		

IMMUNIZATION - EKG

HAVE YOU HAD . . .	NO	YES	HAVE YOU HAD . . .	NO	YES
SMALLPOX VACCINATION (WITHIN LAST 7 YEARS)			POLIO SHOTS (WITHIN LAST 2 YEARS)		
TETANUS SHOT (NOT ANTITOXIN)			AN ELECTROCARDIOGRAM WHEN		

HABITS

DO YOU . . .	NO	YES	DO YOU USE . . .	NEVER	OCC.	FREQ.	DAILY
EXERCISE ADEQUATELY			LAXATIVES				
SWIM?			VITAMINS				
AWAKEN RESTED			SEDATIVES				
SLEEP WELL			TRANQUILIZERS				
AVERAGE 8 HOURS SLEEP (PER NIGHT)			SLEEPING PILLS, ETC.				
HAVE REGULAR BOWEL MOVEMENTS			ASPIRINS, ETC.				
SEX - ENTIRELY SATISFACTORY			CORTISONE				
LIKE YOUR WORK (HOURS PER DAY) ☐INDOORS ☐OUTDOORS			ALCOHOLIC BEVERAGE				
WATCH TELEVISION (HOURS PER DAY)			COFFEE (CUPS PER DAY)				
READ (HOURS PER DAY)			TOBACCO ☐CIGARETTES (PKS PER DAY)				
HAVE A VACATION (WEEKS PER YEAR)			☐CIGARS ☐PIPE ☐CHEWING TOBACCO				
HAVE YOU EVER BEEN TREATED FOR ALCOHOLISM			☐SNUFF				
HAVE YOU EVER BEEN TREATED FOR DRUG ABUSE			APPETITE DEPRESSANTS				
RECREATION: DO YOU PARTICIPATE IN SPORTS OR HAVE HOBBIES WHICH GIVE YOU RELAXATION AT LEAST 3 HOURS A WEEK.			THYROID MEDICATION ☐NO ☐YES, IN PAST ☐NONE NOW NOW ON GR. DAILY				
			HAVE YOU EVER TAKEN . . .				
			☐INSULIN ☐TABLETS FOR DIABETES ☐HORMONE SHOTS ☐TABLETS ☐NO				

WOMEN ONLY

MENSTRUAL HISTORY . . .		NO	YES
AGE AT ONSET	ARE YOU REGULAR ☐HEAVY ☐MEDIUM ☐LIGHT		
USUAL DURATION OF PERIOD DAYS	DO YOU HAVE ☐TENSON ☐DEPRESSION BEFORE PERIOD		
CYCLE (START TO START) DAYS	DO YOU HAVE ☐CRAMPS ☐PAIN WITH PERIOD		
DATE OF LAST PERIOD	DO YOU HAVE HOT FLASHES		

PREGNANCIES . . .	NO	YES		NO	YES
CHILDREN BORN ALIVE (HOW MANY)			STILL BORN (HOW MANY)		
CESAREAN SECTIONS (HOW MANY)			MISCARRIAGES (HOW MANY)		
PREMATURES (HOW MANY)			ANY COMPLICATIONS		

EMOTIONS

ARE YOU OFTEN . . .	NO	YES	ARE YOU OFTEN . . .	NO	YES
DEPRESSED			JUMPY		
ANXIOUS			JITTERY		
IRRITABLE			IS CONCENTRATION DIFFICULT		

AFIT Motion Sickness Laboratory

Motion Sickness Questionnaire

NAME:_____ DATE:_____

RANK:_____ AGE: _____ SEX:_____

ADDRESS: _____

WEIGHT: _____ HEIGHT:_____

This questionnaire is designed to find out:

(a). how susceptible to motion sickness you are, and
(b). what types of motion are most provocative to you.

Section A is concerned with childhood (prior to age 12) experiences of motion sickness.

Section B is concerned with your experiences of motion sickness over the past 10 years.

Section C is concerned with your present susceptibility to motion sickness.

Please read and follow carefully the instructions for each question. The answers are important for evaluating this experiment. This information will be kept in the strictest confidence. Thank you for your help.

Section A

All the questions in this section refer to your childhood experiences of motion sickness, that is, before age 12. We understand you may not remember this very well; just do your best.

	CARS	BUSSES	TRAINS	AIRPLANES	BOATS	SHIPS	PLAYGROUND EQUIPMENT	AMUSEMENT PARK RIDES
(1)Indicate approximately how often you rode on each type (before age 12) by using the following: 0 = no experience 1 = less than 5 trips 2 = between 5 and 10 3 = more than 10								
Considering only those types of transport that you have experience with, answer the two questions below. use the following letters to indicate your response: N=Never; R=Rarely; S=Sometimes; F=Frequently; A=Always								
(2) How often did feel sick while travelling (i.e. queasy or nausea)?								
(3) How often were you actively sick, (i.e. vomiting)?								

Section B

This section is concerned solely with your experiences of motion sickness over approximately the last 10 years.

	CARS	BUSSES	TRAINS	AIRPLANES	BOATS	SHIPS	PLAYGROUND	EQUIPMENT	AMUSEMENT PARK RIDES
(1)Indicate approximately how often you rode on each type (over the last 10 years) by using the following 0 = no experience 1 = less than 5 trips 2 = between 5 and 10 3 = more than 10									
Considering only those types of transport that you have experience with, answer the two questions below. use the following letters to indicate your response: N=Never; R=Rarely; S=Sometimes; F=Frequently; A=Always									
(2) How often did feel sick while travelling (i.e. queasy or nausea)?									
(3) How often were you actively sick, (i.e. vomiting)?									

Section C

This section is concerned with your present susceptibility to motion sickness. If a question does not apply to you, enter "None" or "NA".

(1). What is your current flying status? (Pilot, Navigator, UPT/UNT, etc)._____.

(2). what operational or fully qualified flying experience have you had? (Plane, Hours, Crew position, Command).

_____

(3). I (have have not) been treated for motion sickness. My treatment consisted of _____

_____

for _____ months, at _____

by _____, which (did did not) help.

Treatment did not help because _____

_____

(4). I currently consider myself:

(a). mildly
(b). Moderately
(c). Severely
(d). Not at all . . . . susceptible to motion sickness.

(5). When the opportunity arises, I:

(a). Almost never
(b). Sometimes
(c). Almost always . . . . ride carnival rides

(6). I would describe my current experiences with motion sickness as:

(a). Totally disabling
(b). Occasionally disabling
(c). Debilitating but not disabling
(d). Only bothersome
(e). Not affected

(7). When I have been airsick on a flight, I:

(a). Almost always
(b). Sometimes
(c). Almost never . . . . have trouble deplaning.
(d). No airsickness experienced.

(8). Other members of my family are susceptible to motion sickness.

(a). Do not know
(b). No
(c). Yes (elaborate)_____

(9). The following symptoms usually accompany my experience of motion sickness: (circle all that apply)

Nausea	Dizziness
Vomiting	Disorientation
Sweatiness	Desire to be left alone
Gassiness	Yawning
Coldness	Difficult concentration
Churning stomach	Tingling hands and feet
Reluctance for physical or mental work	Objects/sounds seem distant
Headache	Chest pains
Fatigue or drowsiness	Distractibility
Faintness	Thick headedness
Blurred/tunnel vision	Spaced out

Other (elaborate) _____

(10). I have found the following situations and their accompanying body motion sensations to be pleasant (P) or unpleasant (U) for the most part: (Indicate any not experienced by "NA").

_____Fast elevator rides	_____Gymnastics
_____Escalator rides	_____Inverted flight
_____Dancing	_____Mountain driving
_____Inflight positive Gs	_____Hammocks
_____Inflight negative Gs	_____Tipsy from drinking
_____Skiing (water/snow)	_____Jogging
_____Train/subway rides	_____Skating
_____Swings	_____Motorcycle riding
_____Merry-go-rounds	_____Glider/small planes
_____Roller coasters	_____Boating
_____Other midway rides	_____Low level flight
_____Stationary spinning	_____Ships

_____Other (elaborate) _____

(11). Have you ever been eliminated from a flying training program?

_____No
_____Yes (elaborate) _____

(12). Are you currently taking any medications (including aspirin and antihistamines)?

_____No
_____Yes (specify) _____
How long? _____

(13). Have you had any alcohol in the last 24 hours?

_____No
_____Yes

(14). How long ago was your last meal? _____Hours

(15). Have you had any unusual motion stimuli in the past 24 hours (aircraft rides, carnival rides, etc?)

_____No
_____Yes (specify) _____

(16). Have you had any vision problems recently (general worsening, change in prescription of corrective lenses, etc.)?

_____No
_____Yes (specify) _____

(17). Have you had any stomach upsets in the past month?

_____No
_____Yes

(18). What is your current assessment of your health?

_____Excellent _____Good _____Fair _____Poor

(19). What can you add that might be beneficial to this study or that would improve this questionnaire?

Appendix B: AFIT Susceptibility Test

The A.F.I.T. susceptibilty test is designed to predict a persons susceptibility to motion sickness using the same order of head movements used during standard AFIT motion sickness experiments (9:152). Chair rotation speeds can then be selected to standardize the time of rotation for different subjects to within a few minutes (3). Unlike the motion sickness experiment, the susceptibility test does not terminate with emesis. The test is terminated when the subject just reaches a self reported symptom level of seven.

Procedure

1. Interview the subject.
   - A. Personally perceived susceptibility to motion sickness.
   - B. General physical condition.
   - C. Drugs drugs taken recently (if any, consult the physician before proceeding).
   - D. Have the subject read and sign the AFIT Motion Sickness Lab Motion Sickness Consent Form and its addendum.
2. Explain the symptom rating scale and the head movement commands to the subject.
3. Prepare to write down the symptoms and the head movement number.
4. Assist the subject in mounting the chair.
5. Blindfold the subject.
6. Clear the area around the chair.

7. Turn on the chair power by pushing up the AC power control breaker and press the reset button on the right console (if the program control start/stop button is not lit, press it also).

8. Slowly rotate the chair clockwise by turning the control knob for left and right motion to the right while viewing the angular velocity gauge on the middle console. Turn the knob until an angular velocity of 14 RPM is reached.

9. Wait one minute for the subject to stabilize.

10. Order head movements (9:152) while the subject reports his symptoms.

11. Stop head movements when one of the following apply.

    A. When the subject requests ending the experiment.

    B. When the subject reports a symptom level of seven or higher.

    C. When the subject has severe symptoms (vomiting, retching, etc.).

    D. If the subject is in any sort of distress.

    E. If six minutes have elapsed from the start of rotation.

12. Instruct the subject not to move his head after the termination point of the experiment is reached.

13. Allow the subject's symptoms to begin decreasing.

```
* * * * * * * * * * * * WARNING * * * * * * * * * * * **
*                                                       *
*      CEASE DECELERATION IF THE SUBJECTS SYMPTOMS      *
*    WORSEN AND DECELERATE SLOWLY AFTER THEY STABLIZE   *
*                                                       *
* * * * * * * * * * * * * * * * * * * * * * * * * * * **
```

14. Slow the chair at approximately 5 RPM per minute while querying the subject about his symptoms.

15. Turn off the chair power after it stops rotating.

16. Allow the subject's symptom level to return to a one.

17. Assist the subject in dismounting chair.

Appendix C: Calibrations

All of the following calibrations require at least two people (one to monitor the recording equipment and write down readings, and another to perform tasks and make equipment adjustments. If the experimenters are novices, they should consider practicing the calibrations before they perform an actual experiment.

Plethysmographs

* * * NOTE * * *

Plethysmographs are used to quantize facial skin pallor. One hand of the subject is exsanguinated to calibrate the sensors. In order for the calibration to be accurate, the sensors must be placed on areas of the hand with skin tone similar to the face.

1. Plug the plethysmograph sensors into the circuit card rack on the motion sickness chair.
2. Turn on the circuit card rack.
3. Attach the two plethysmograph sensors to the subject's hand (use tape over the top of the sensor or a two way donut adhesive under it) making sure not to deform the skin. Also, secure the leads by taping them to the subject's arm.
4. Turn on the strip chart recorder (slow speed to conserve paper).
5. Adjust the offset on the circuit card for zero volts on both channels while subjects hand is level with his waste.
6. Have the subject lift his hand above his head, then lower it below his waste.

* * * NOTE * * *

Make the gain adjustments in step 7 only if necessary. It is desirable not to make any adjustment at all.

7. Observe a pen deflection of slightly less than one volt on the strip chart for both channels. If not, adjust the gain on the circuit card for that channel (see fig. 11, clockwise to increase, counter clockwise to decrease).

8. Repeat steps 6 and 7 until the gain settings are acceptable.

9. Remove the sensors and stop the strip chart recorder.

10. Exsanguinate the subject's hand.

    A. Put a blood pressure cuff loosely around the subject's forearm.

    B. Have the subject squeeze his fist tightly (this is more effective if the subject has something to grip).

    C. Tightly wrap an Ace Bandage around the subject's arm starting at the fingers and ending half way up the forearm squeezing out blood in the process.

    D. Put the blood pressure cuff over the end of the ace bandage, then tighten and inflate it to approximately 220 mm Hg.

    E. Remove the ace bandage and have the subject flex his hand to redistribute the remaining blood.

11. Attach the plethysmograph sensors to the same parts of the hand used in step 3.

12. Start the necessary recording equipment (beta tape recorder and strip chart recorder).

13. Ensure the signals are not at end points of the strip chart recorder. If so, readjust the offsets to put them within limits.

14. Release pressure from the blood pressure cuff.

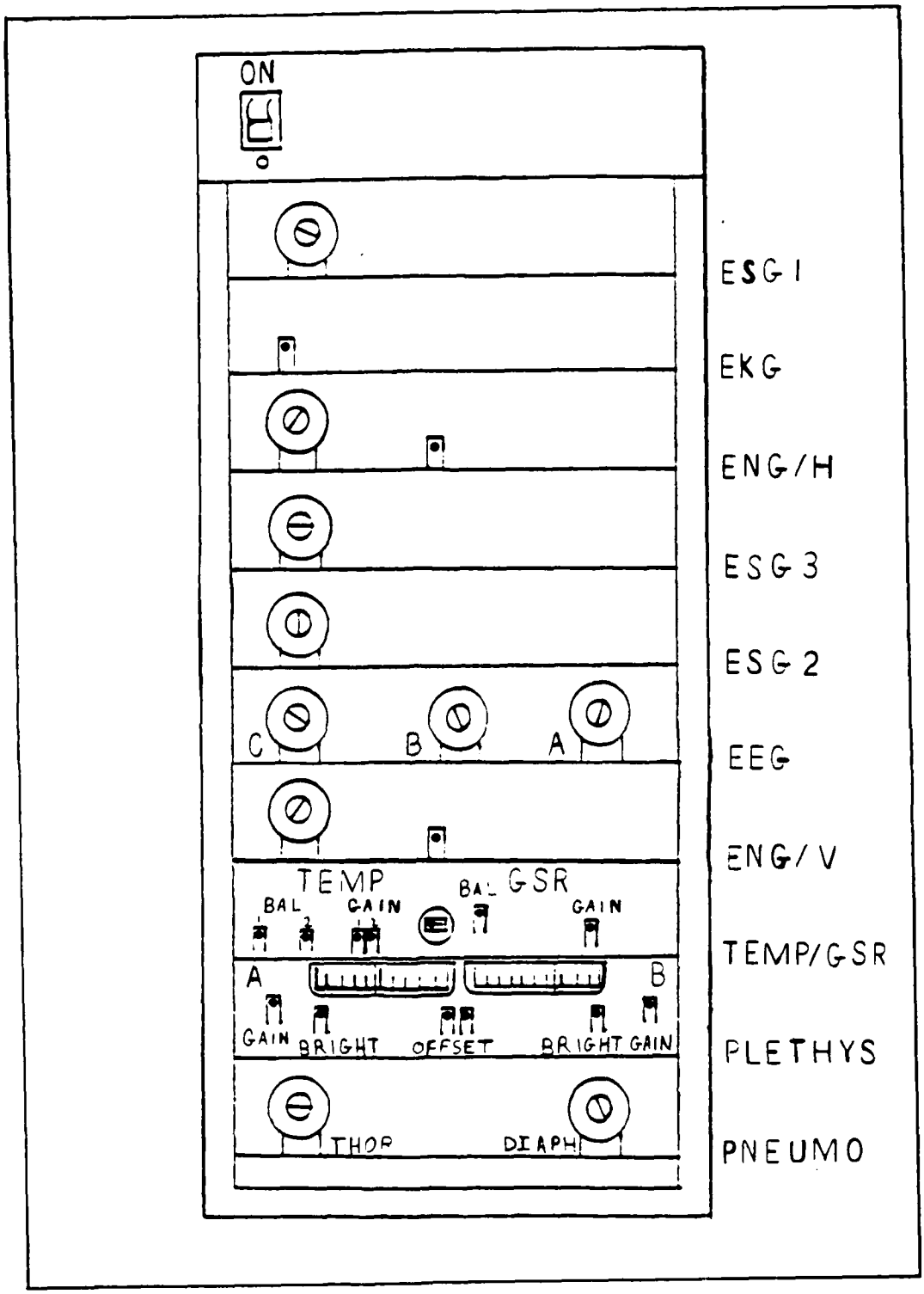

Fig. 11 Circuit Card Rack.

15. Observe the color change in the subject's hand and the pen deflections on the strip chart recorder. If the pen deflections are within limits of the strip chart recorder, then the calibration is complete. If not, then steps 3 through 15 should be redone adjusting gains and offsets properly.

16. Stop the recording equipment and remove the sensors and the blood pressure cuff from the subject.

Galvanic Skin Response

* * * NOTE * * *

This calibration does not involve the subject and can be done during other calibrations.

1. Plug the GSR sensor into the circuit card rack.

2. Start the recording equipment.

3. Switch the knob on the GSR circuit card to the subject position (see fig. 11) and short the leads together to obtain zero ohms resistance.

4. Record for 5 seconds then put the knob in the 20, 100, 400, 800, and 1600 kilohm positions recording for 5 seconds each. Annotate each position on the strip chart recorder.

5. Switch the knob back to the subject position and stop the recording equipment.

Pneumographs

* * * NOTE * * *

This calibration should be performed after the subject is in the chair and final adjustments have been made on the pneumograph straps.

1. Start the strip chart recorder.

2. Have the subject blow large, normal, and small breaths into the spirometer.

3. Mark the beginning and end of each breath measured and label each with the volume measured on the spirometer.

Appendix D: Subject Physical Exam

1. Eye range of motion.
2. Observation of nystagmus.
3. Eye convergence.
4. Pupillary light reflex.
5. Weber and Rinne tests.
6. Cranial nerve overview.
7. Pulmonary auscultation.
8. Cardiac auscultation.
9. Gastrointestinal auscultation.
10. Balance tests.
    A. Eyes open, heels together.
    B. Eyes closed, heels together.
    C. Eyes open, standing on single foot, closing eyes (repeat for other foot).
    D. Romberg's test (heel to toe balance test, eyes open and closed).
11. Finger-nose coordination.
12. Hand alternation (dysdiadokokinesis).
13. Deep tendon reflexes.
14. Symmetry (standing, arms together/outstretched, eyes closed).
15. Blood pressure.
16. Electrocardiogram (after sensor is attached).
1 . Electroencephalogram (after sensors are attached).

Appendix E: Circuit Schematic Diagrams

The schematic diagrams of the circuits used in the motion sickness sensors were taken from the notes of Dr. Czelen (1). They were current as of this thesis; however, if diagrams should be needed in the future, Dr. Czelen should be consulted.

Some circuits cards have two or more identical circuits. This is noted by the multiplication factor following the title. The circuits are presented in the following order:

a. Five Volt Power Supply.

b. Electrocardiograph.

c. Photoplethysmograph X 2.

d. Pneumograph X 2/Ballistocardiograph.

e. Electrosplanchnograph.

f. Electronystagmograph.

g. Temperature X 2.

h. Electroencephalograph X 3.

i. Galvanic Skin Response.

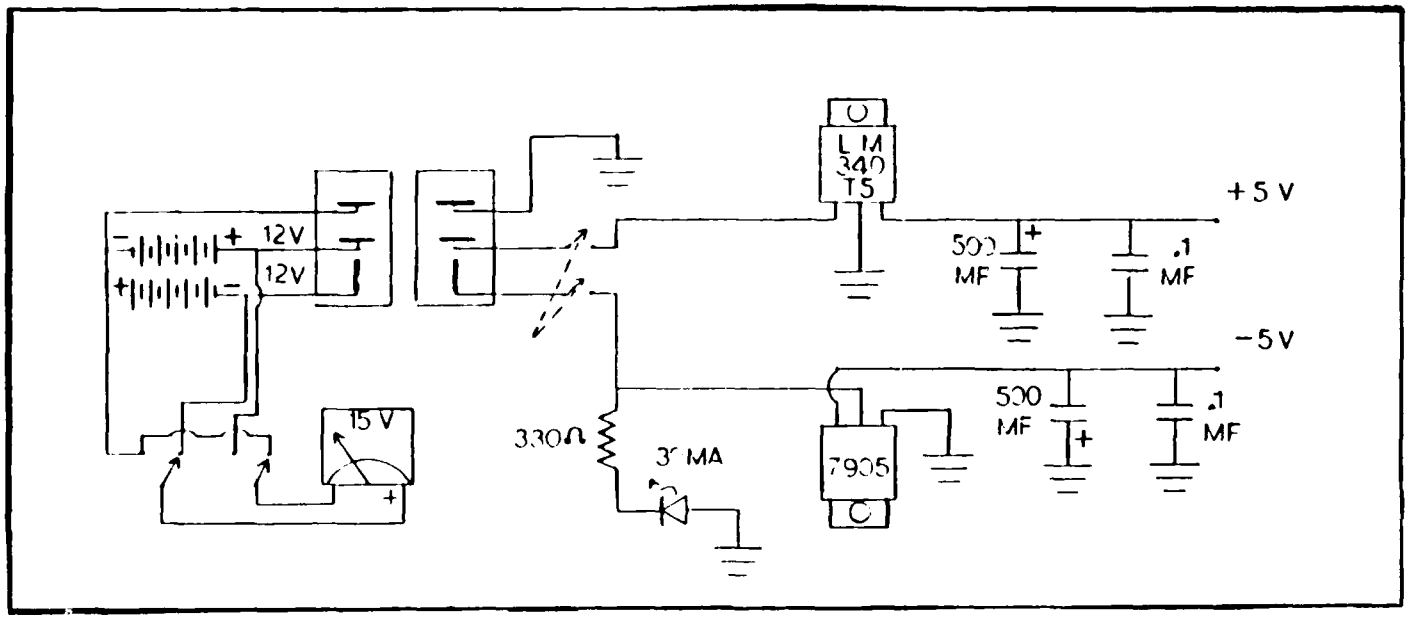

Fig. 12 Five Volt Power Supply (1).

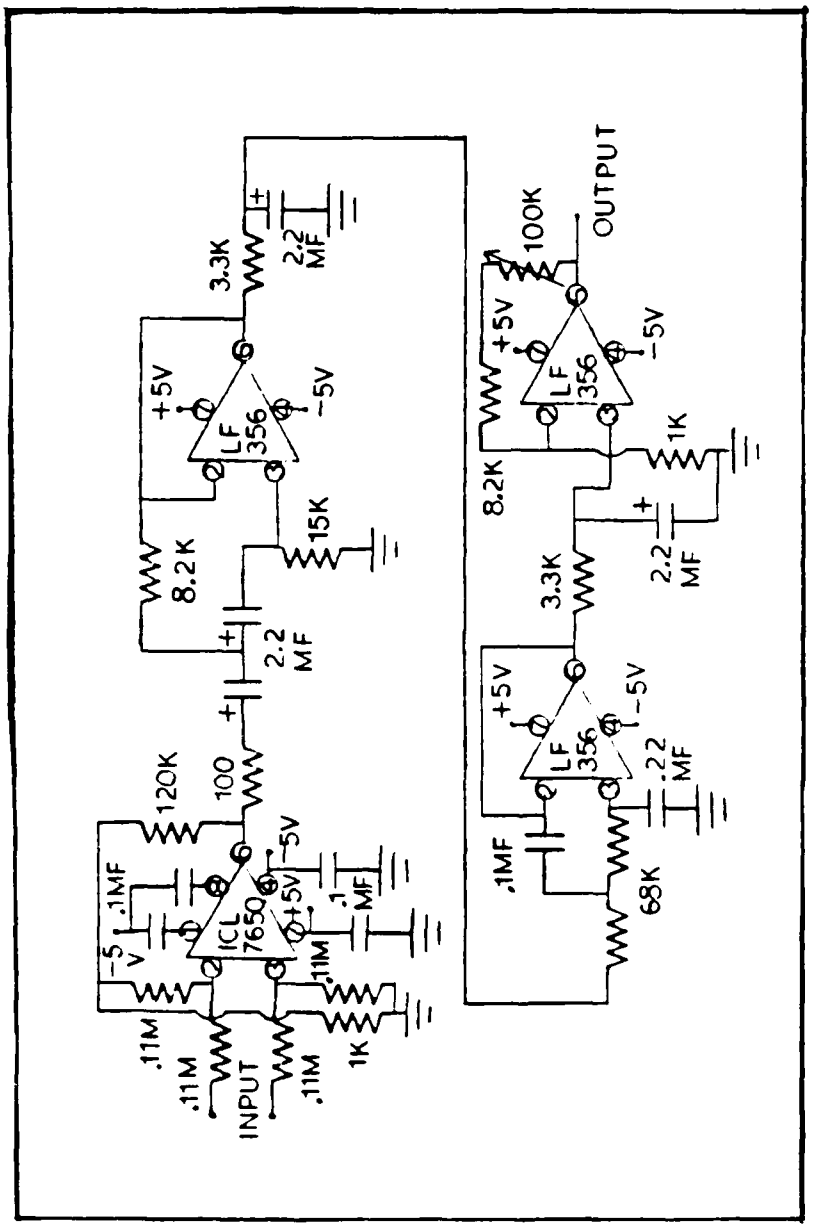

Fig. 13 Electrocardiograph (1).

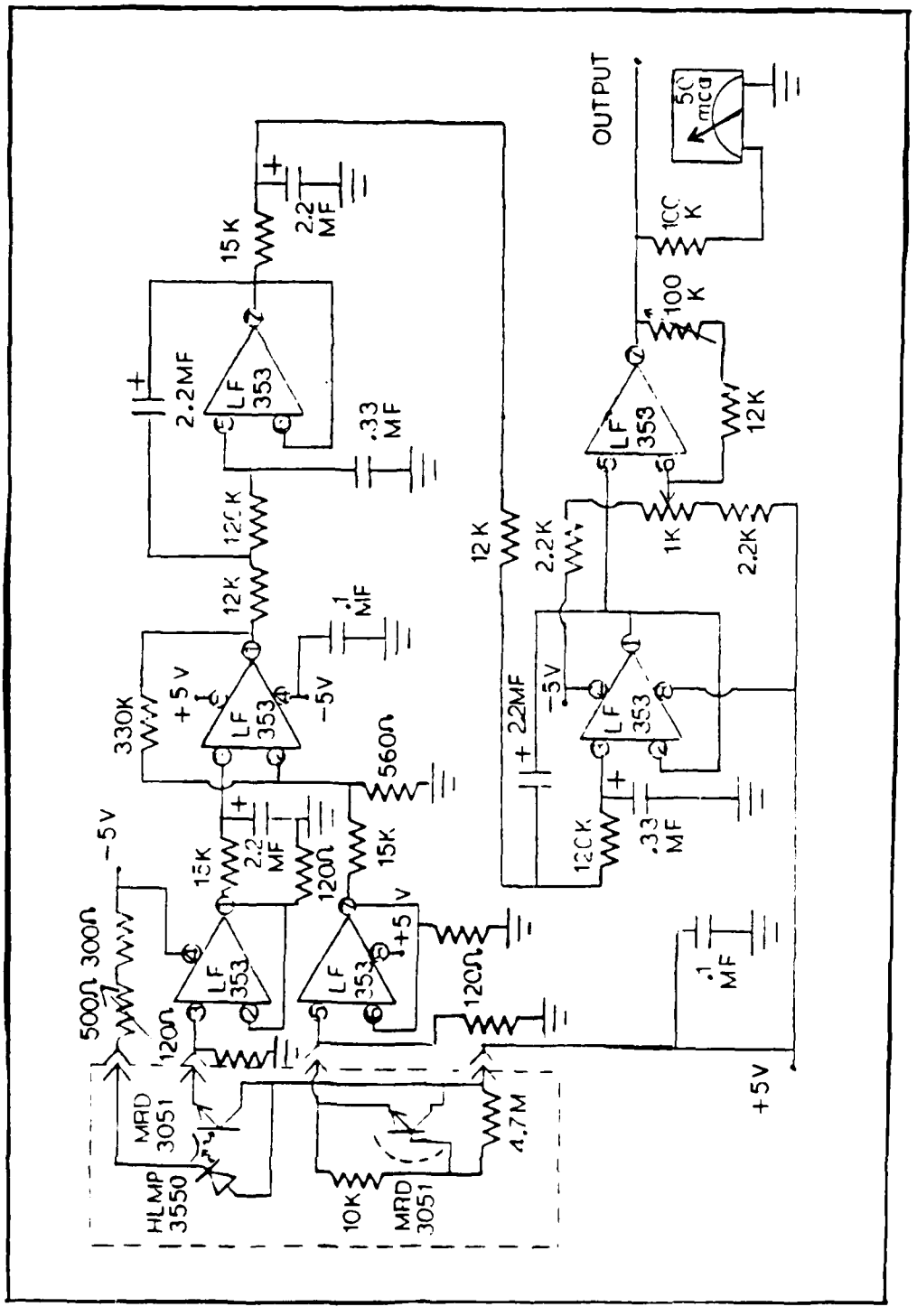

Fig. 14 Photo-plethysmograph x 2 (1).

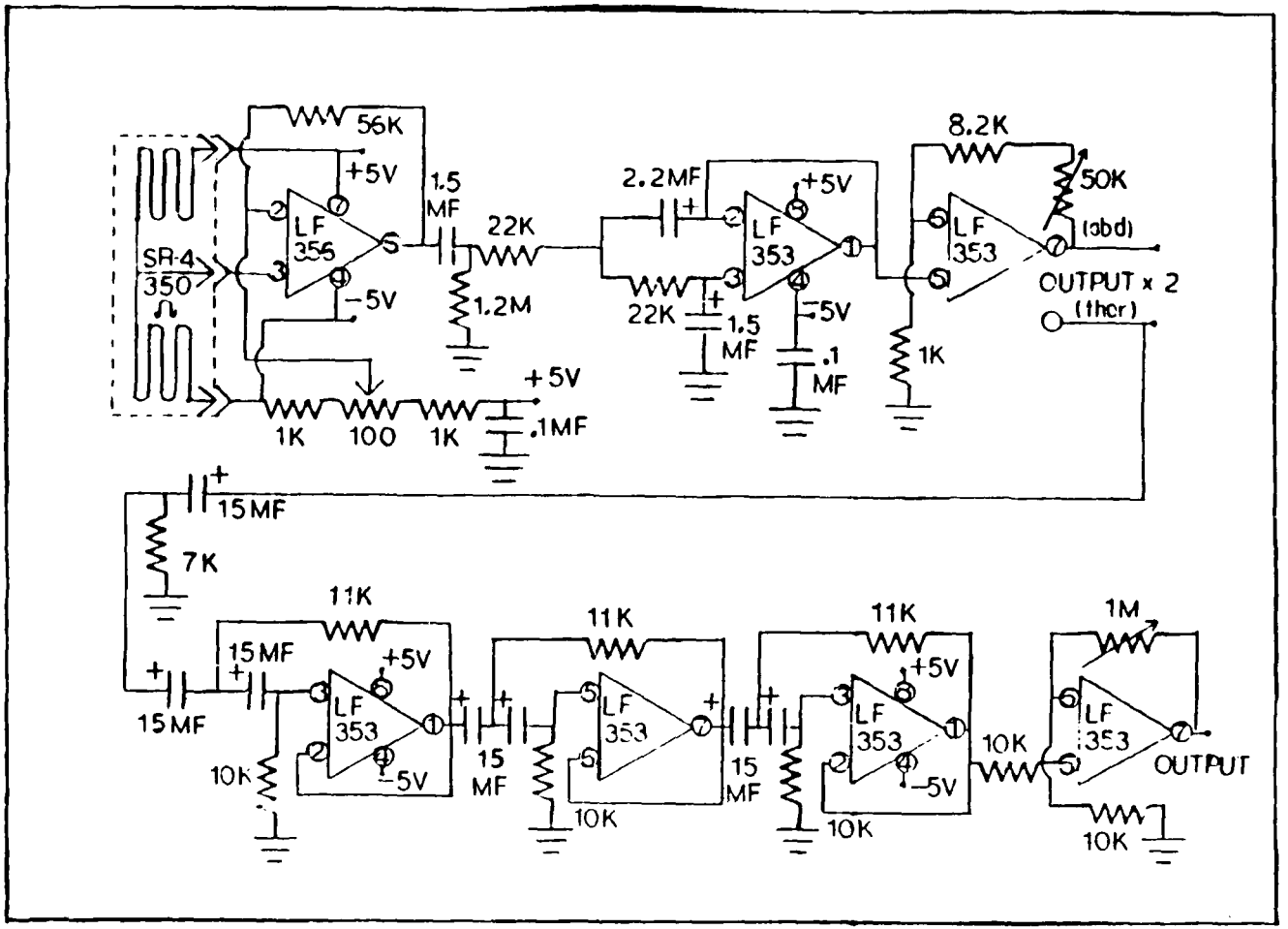

Fig. 15 Pneumograph X 2/Ballistocardiograph (1).

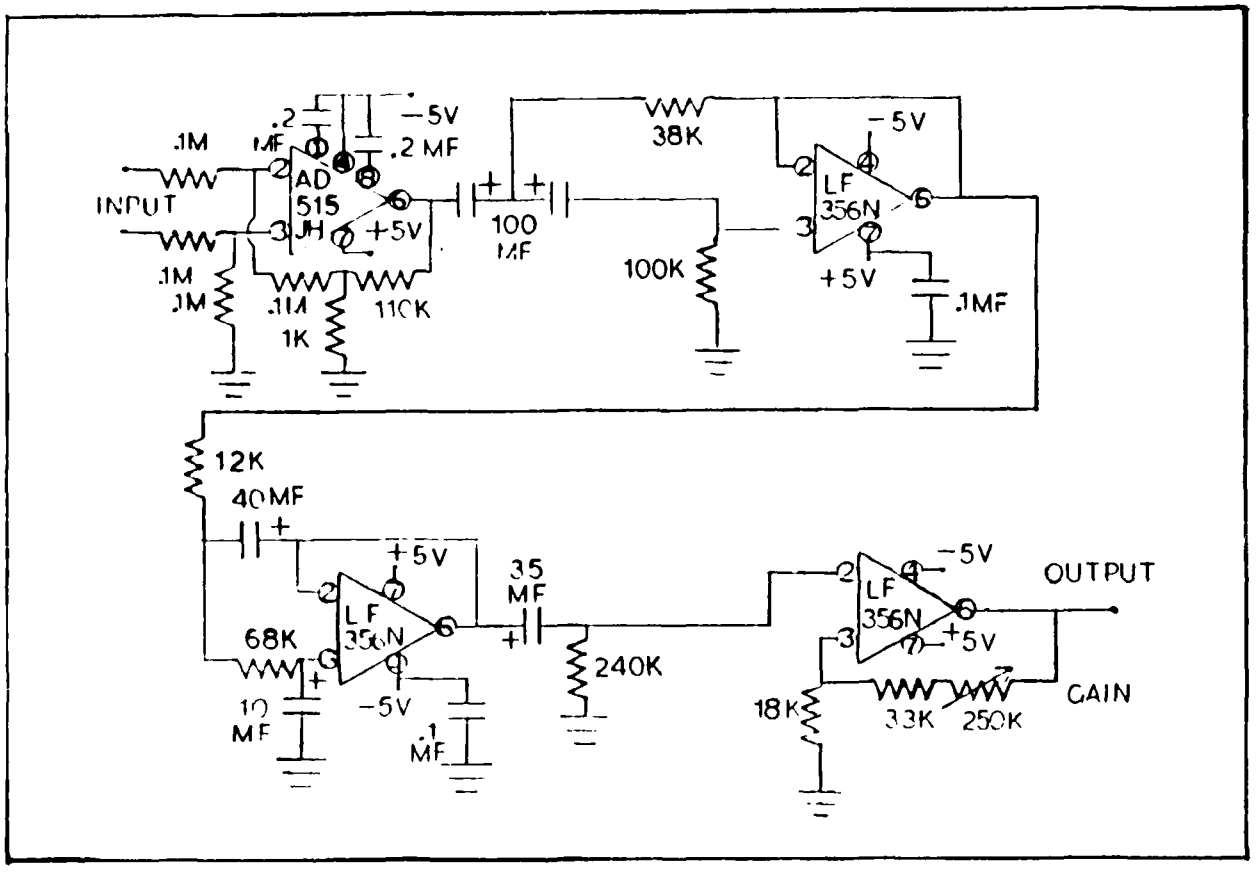

Fig. 16 Electrosplanchnograph (1).

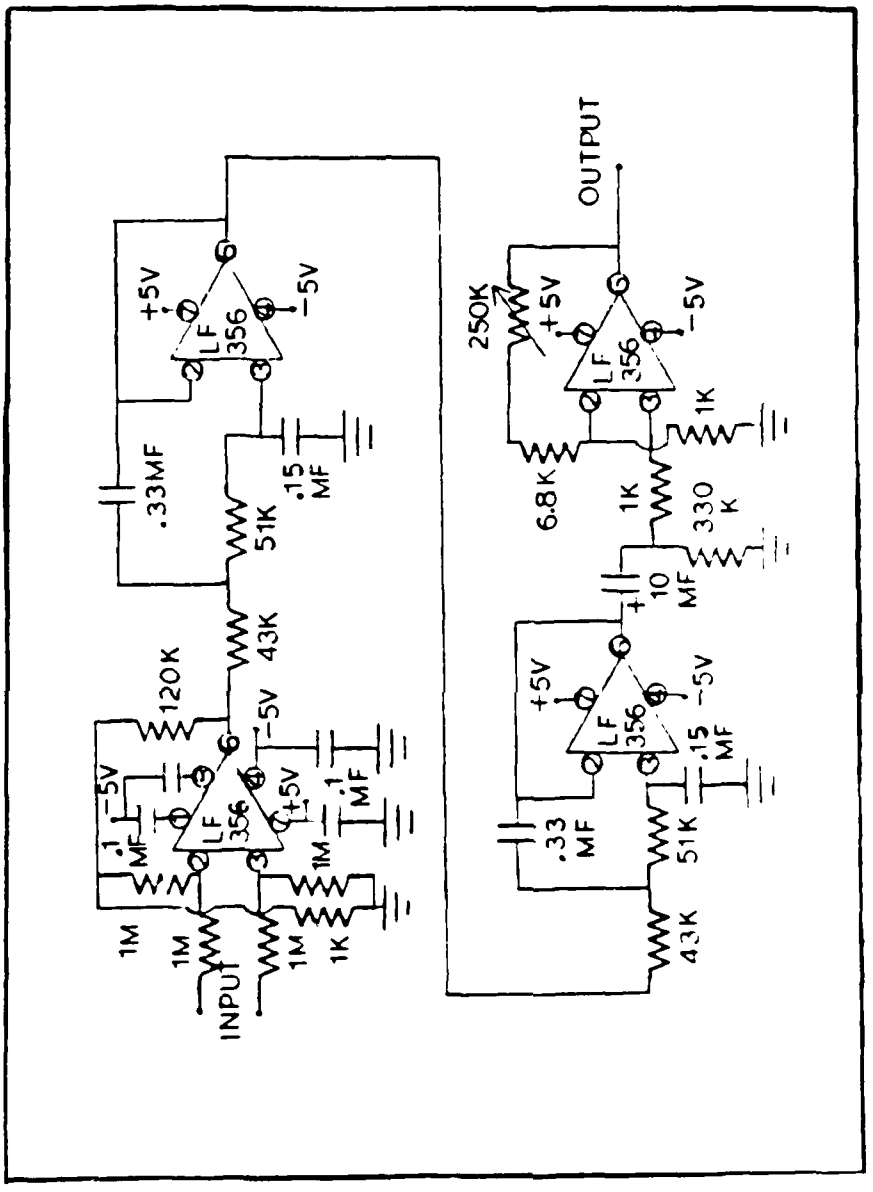

Fig. 17 Electronystagmograph (1).

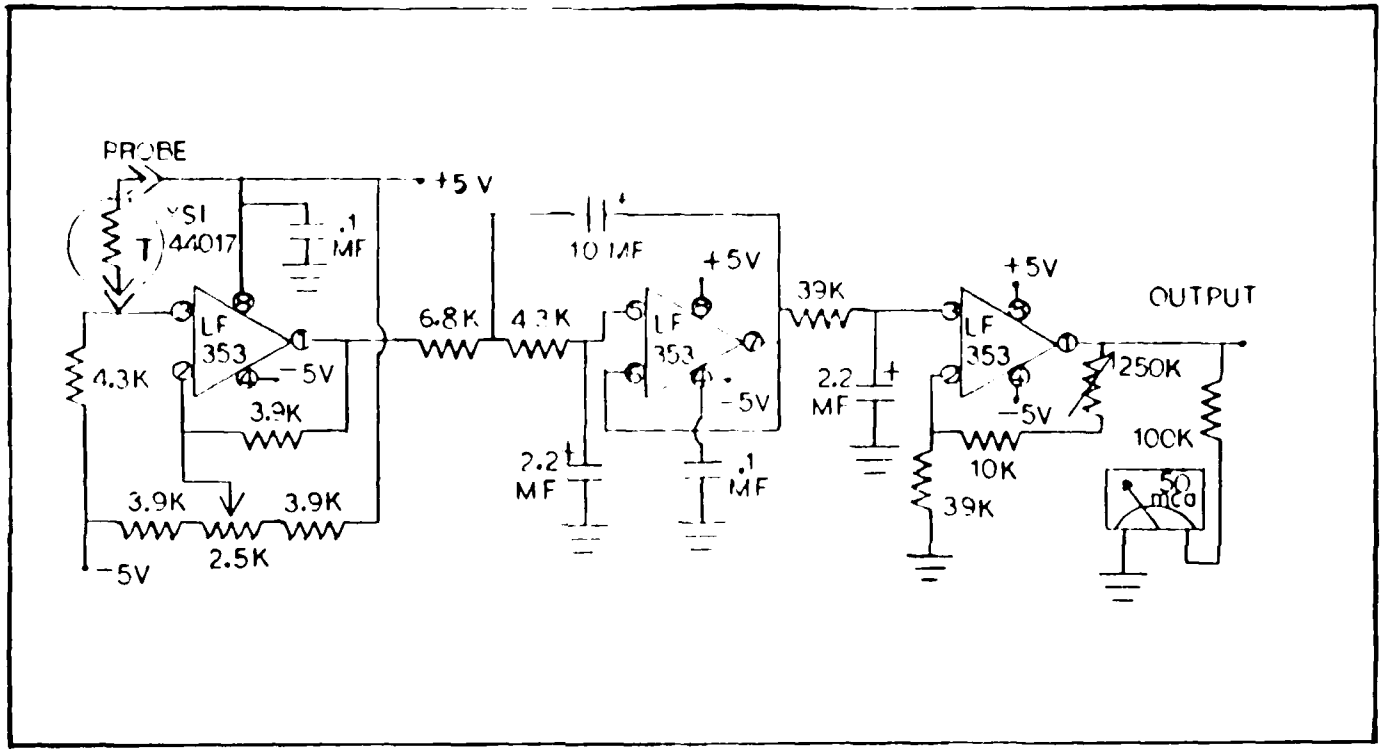

Fig. 18 Temperature X 2 (1).

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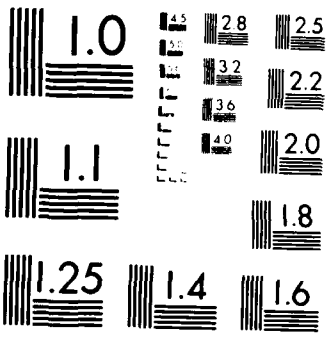

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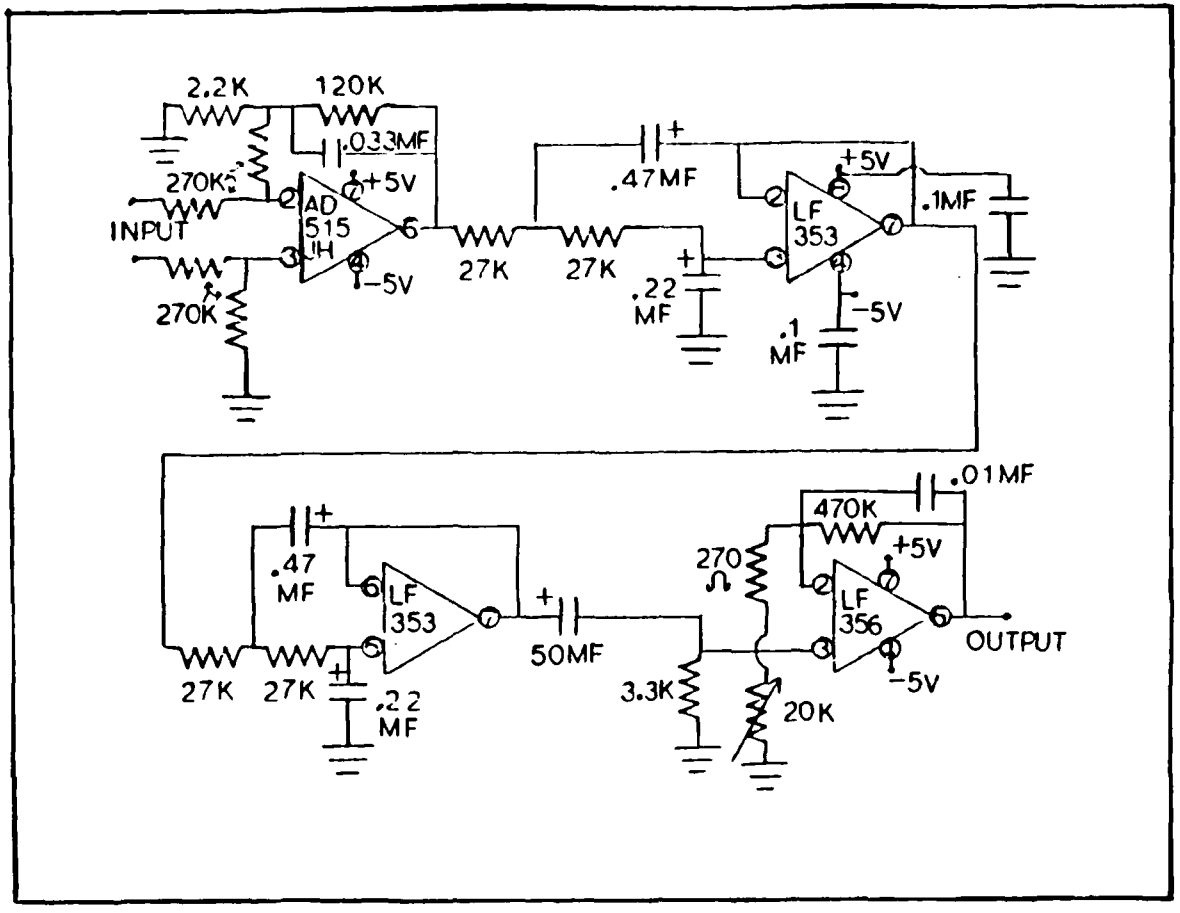

Fig. 19 Electroencephalograph X 3 (1).

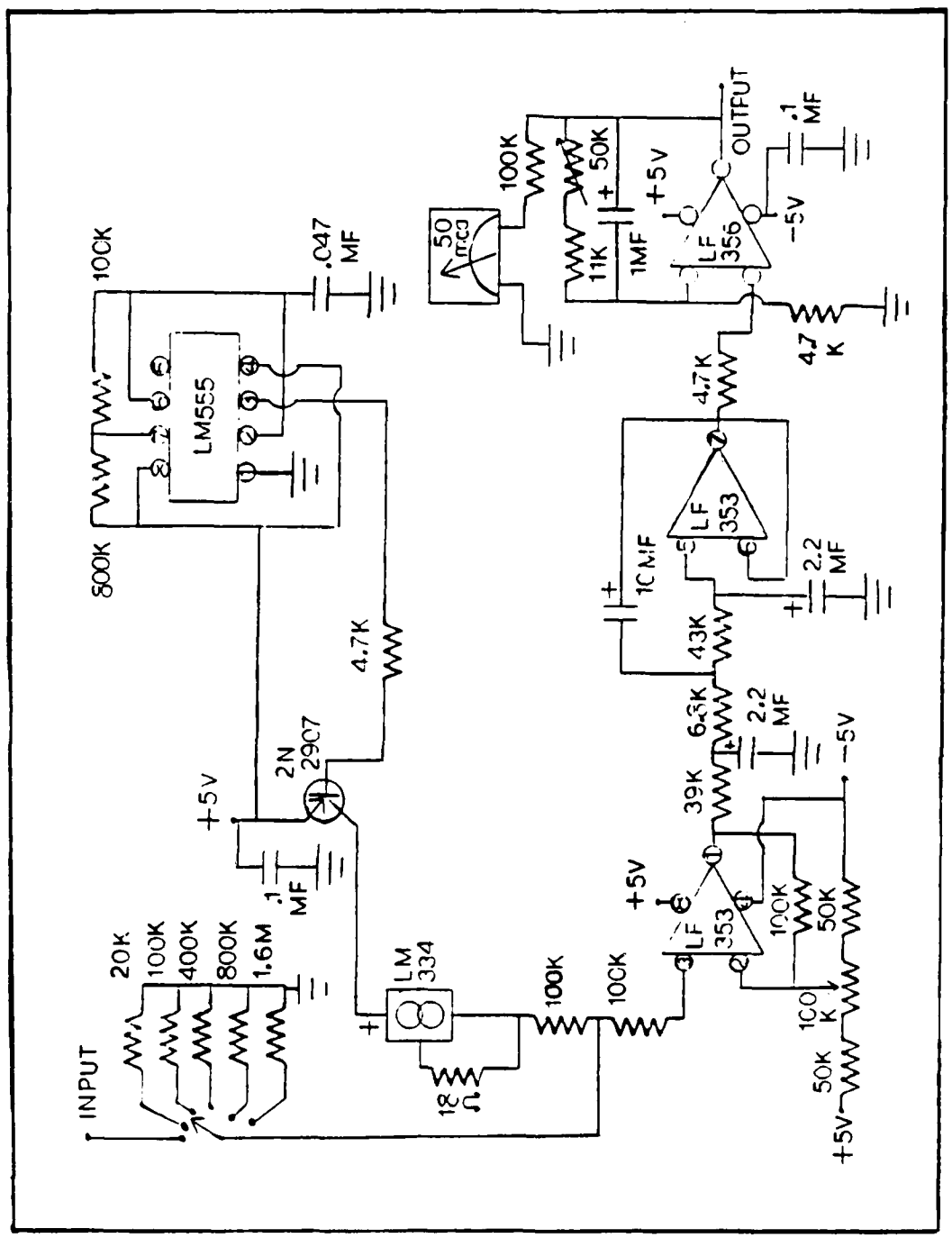

Fig. 20 Galvanic Skin Response (1).

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VITA

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Captain Gaudreault's first assignment on active duty was to Keesler Technical Training Center for a six week course for Communications Electronics Engineers. After completing this course, he was assigned to the 1815th Operational Test and Evaluation Squadron at Wright-Patterson Air Force Base, Ohio. He attended a course on high frequency communications at the 1815th Systems Evaluation School and was a assigned as the team chief of a high frequency evaluation team. In May, 1986 he was assigned to the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

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BLOCK 19. (Abstract)

The purpose of this thesis project was to study motion sickness by inducing it on volunteer subjects and monitoring several of their physiological parameters. This was part of an ongoing project to study motion sickness at the AFIT. During this thesis period, the existing procedures and methods for collecting and analyzing data were revised, and data were collected on sixteen human subjects. Data and analysis of cardiograms, encephalograms, pneumograms, splanchnograms, and plethysmograms are presented in this thesis.

Analysis of the data revealed several findings. Heart rates increased during motion sickness for all subjects, but rates slightly decreased just prior to emesis and increased again after emesis for about half of the subjects. Some encephalograms showed high amplitude low frequency activity as in previous experiments done at AFIT, but they also showed slowed alpha activity. The pneumograms showed that intake volumes at least doubled on all subjects during motion sickness signifying the occurrence of hyperventilation. Splanchnograms showed an increase in amplitudes and frequencies of electrical activity and a decrease of mechanical activity. And plethysmograms showed blood volume in the skin decreased during motion sickness.

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